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A COMPARISON OF LINE-SCAN AND PHOTOGRAPHIC IMAGES FOR TARGET IDENTIFICATION

25X1

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A COMPARISON OF LINE-SCAN AND PHOTOGRAPHIC IMAGES FOR TARGET IDENTIFICATION

Technical Report 723-12

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October 1969

ACKNOWLEDGMENTS

We sincerely thank the photointerpreters who participated in this study [redacted] valuable assistance in evaluating the photography, obtaining the subjects, and gathering the data.

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Declassified in Part - Sanitized Copy Approved for Release 2012/08/22 : CIA-RDP79B00873A001600040028-4

ABSTRACT

The study reported here was the first effort to determine the relation between line-scan and photographic images in terms of photointerpreter target identification performance. Two line-scan image variables were investigated: signal-to-noise ratio and number of scans per target. One photographic image variable was investigated: ground resolution. The targets were models of tanks and miscellaneous vehicles, and the subjects were 50 professional photointerpreters. The data were analyzed to determine what combinations of the two line-scan variables were equivalent to photographic ground resolution in terms of percent correct target identification.

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A COMPARISON OF LINE-SCAN AND PHOTOGRAPHIC IMAGES FOR TARGET IDENTIFICATION

INTRODUCTION

There have been several studies of the effects of photographic ground resolution on the intelligence output of photointerpreters (PIs) and intelligence analysts.[1] There have been fewer studies of the effects of line-scan imagery on intelligence output. The purpose of the study reported here was to make an initial determination of the relation between line-scan and photographic imagery in terms of PI target identification performance. The relations between the two types of imagery should be determined so that the designers of line-scan systems can use the results of the research on the effects photographic ground resolution has on the performance of different PI and analyst tasks.

[redacted] 25X1

recently completed an experimental study to determine the informative value of static line-scan images as a function of two variables: (1) number of scans per target and (2) signal-to-noise ratio.

[redacted] 25X1

In the [redacted] study, photographs were taken of 20 scale model vehicles (the "targets"): 10 tanks and 10 miscellaneous vehicles, such as trucks and armored cars. The photographs were transformed into line-scan transparencies to produce 16, 32, or 48 scans per target. Gaussian noise was added to the transparencies producing six signal-to-noise ratios for each of the three numbers of scans. Because the noise was added, it was independent of the signal. There was also a noiseless image for each of the three numbers of scans. 25X1

The subjects were 54 college students. Each subject was assigned randomly to one of six groups, and each group viewed three transparencies that contained the same amount of noise but a different number of scans per target. The targets were in different positions in the three transparencies. The actual models used as targets were mounted on a board in front of the subjects, and the subjects' task was to match each target image with each target model, a task similar to the operational task of matching a target image with the target as shown in ground photography or as portrayed in a PI key.

In the data analysis, the tanks were treated as one class of targets and the miscellaneous vehicles were treated as another. Matching a target image with the target model was considered a correct "identification," and the percentage of correct identifications was computed for each target class and each experimental condition. The results of the study were reported [redacted] 25X1 *The informative value of line-scan images as a function of signal and noise characteristics (white, Gaussian, signal-independent noise)*, [redacted] Report No. 9614, March, 1969. 25X1 Some of the data are also presented in the "Results" section of this report.

METHOD

The method used in the study reported here was similar to that used by [redacted] However, the 25X1 subjects, who were experienced PIs, not only viewed the line-scan imagery used in the previous study, they also viewed conventional photographic transparencies of the same targets at five different ground resolutions. They viewed the two types of imagery independently.

Their task was to match the line-scan target images and conventional photographic target images with the target models. The percentage of correct identifications was computed both as a function of number of scans per target and signal-to-noise ratio in the line-scan images, and as a function of photographic ground resolution.

Preparation of the Images

Following are descriptions of how the line-scan and photographic transparent images were prepared [redacted] The 25X1 line-scan images used in the study reported here were the same ones used by [redacted] and a more com- 25X1 plete description of the image preparation is given in their report.

The line-scan images. The model targets were placed on a uniform background and the position of each was random. They were placed so that all of them extended an equal distance in the direction perpendicular to the scan direction. This was done so that each image would be formed by approximately the same number of scan lines.

A diffuse light source was used to simulate the illumination of the sky, and another point light source was used to simulate the sun at 50° above the horizon.

Three different random arrangements of the models were photographed with Kodak High Definition Aerial Film, Type 3404, in a 35mm camera. Each photograph was enlarged so that the subsequent conversion into line-scan images would result in 16, 32, and 48 scans per target.

The enlarged photographs were transformed into line-scan images using the [redacted] Line-Scan Image Generator[2] and 25X1 associated Digital Tape Memory System.[3] (See Appendix A.) The sampling and reconstruction spots were identical and circularly symmetrical; they had Gaussian intensity distributions with half-amplitude diameters of 0.55mm. The scan spacing was 0.55mm.

The photographs were sampled at intervals of 0.55mm, the half-amplitude of the spot diameter. The sampled transmittance was quantized into 12 bits (virtually analog imagery) and recorded digitally on tape.

Noise was added to the quantized transmittance producing an output image with the desired noise characteristics. The noise elements were generated using a random-number-generator subroutine on an SDD 930 computer.

The noise had a Gaussian transmittance distribution, and different standard deviations of the distribution were used to produce signal-to-noise ratios of 3, 5, 10, and 20.[4]

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[2]Scott, F. A line-scan image generator, *Photo Sci. & Eng.*, Vol. II, 5, 1967.

[3][redacted] *Informative value of dynamic images as a function of signal and noise characteristics*, Phase 1, Task 2. [redacted] Report No. 9226, May, 1968. 25X1 25X1

[4]A signal-to-noise ratio of 30 was also used in the [redacted] 25X1 [redacted] study. It was not used in the study reported 25X1 here because identification performance with it was not significantly different from performance with noiseless line-scan imagery.

The signal-to-noise ratio was defined as the ratio of the standard deviation of the signal to the standard deviation of the noise in transmittance space.

When the signal and noise can be determined independently in terms of electrical energy, as the transmittance values were determined, the signal-to-noise ratio can be expressed in decibels as follows: $S/N \text{ (db)} = 10 \log_{10} \frac{S}{N}$. Thus the signal-to-noise ratios in transmittance of 3, 5, 10, and 20 correspond respectively to 9.54, 13.98, 20.00, and 26.02 decibels.

Fourteen line-scan image transparencies were produced with the characteristics shown in Table 1. Each cell in the table represents a line-scan transparency characterized by the column and row values. (Note that a transparency was not made to represent 48 scans and a signal-to-noise ratio of 20, because it would have been almost identical to the noiseless imagery.)

TABLE 1
CHARACTERISTICS OF THE LINE-SCAN TRANSPARENCIES

NUMBER OF SCANS PER TARGET	SIGNAL-TO-NOISE RATIO				
	3	5	10	20	∞ (Noiseless)
16					
32					
48				*	

*A transparency was not made to represent this cell.

Each transparency contained the images of the 20 model targets. The position of the vehicles was the same in all transparencies represented by each row in the table but differed from one row to the next.

Copies of the line-scan image transparencies are shown in Appendix B. The quality of them is not as good as the ones used in the study, because they are second generation.

The photographic images. The photographic images used in the study were made by [redacted] from the original negative used in making the 48 scan, line-scan images.[5] The method used is described in Appendix C, which is a copy of the [redacted] report submitted to [redacted] with the photographs.

The ground resolution of the five photographs was determined from the average of the three-bar target readings made by three photographic scientists. The ground resolutions were: 5", 10", 27", 38", and 43".

The quality of the photographic images was selected to extend across the range of qualities currently being produced by operational systems, as well as those expected from future systems. The modulation transfer functions (MTFs) of the experimental photographs were compared with an MTF obtained from an operational photograph. They were very similar. Such a comparison is not entirely valid, however, because the edges traced in the two types of photographs were not the same.

Copies of the photographic images are shown in Appendix D. They are not quite as good as the ones used in the study because they, like the line-scan images shown in Appendix B, are second generation.

The Targets

Figure 1, Page 7, is a reproduction of a photograph of the models used as targets in the study.

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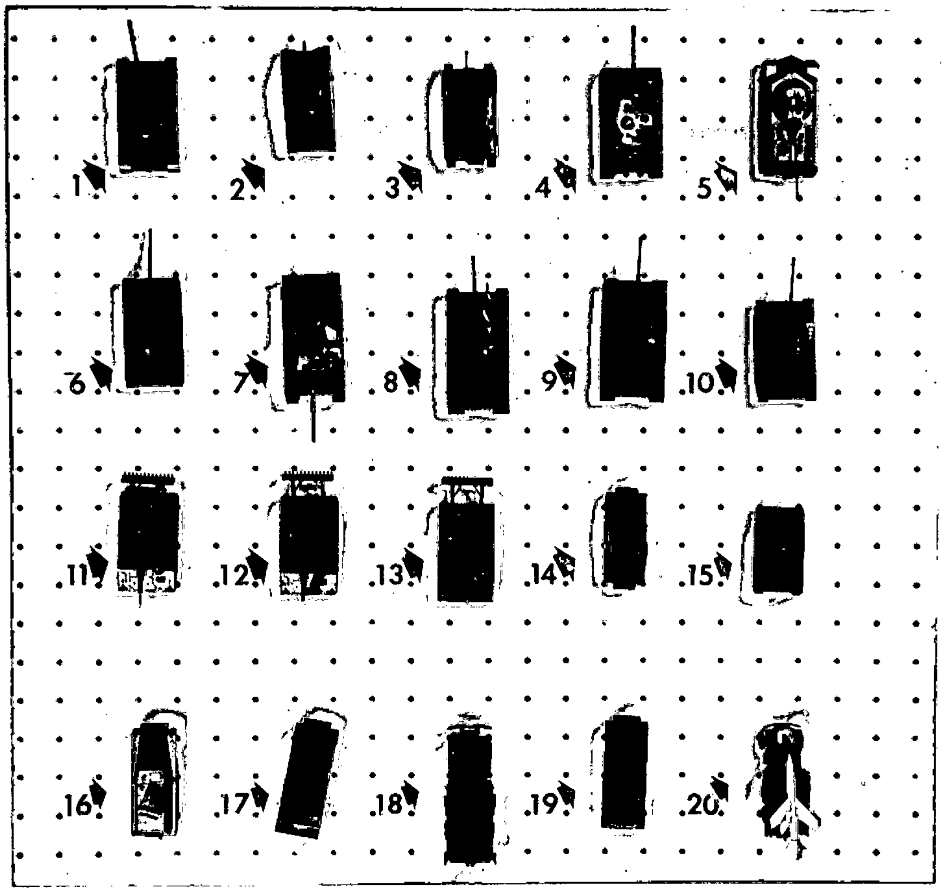
[5]After they were prepared, the photographs were cut and the targets rearranged so that their position would not be the same as their position in the 48 scan, line-scan images.



1. Russian T-54 Tank
2. U. S. Medium Sherman M4, A4 Tank
3. German Tank IV/H
4. German Tiger (1) Tank
5. Joe Stalin III Tank
6. U. S. Medium M-60 Tank
7. British Centruion Tank
8. U. S. Medium Patton M-47 Tank
9. French Medium Tank AMX30
10. U. S. Light "Walker Bull-dog" M-41 Tank
11. Tank Recovery Vehicle T-119
12. Tank Recovery Vehicle T-120 (1)
13. U. S. T-120 Tank Recovery Vehicle
14. German 234/1 Armored Car
15. U. S. M-106 Mortar Carrier
16. German Half Track Rocket Carrier
17. Half Track - Munition Carrier
18. U. S. M-62, 5-Ton Wrecker Truck
19. German Sound Detector
20. U. S. La-Cross Missile XM 4 E2

Figure 1. The model targets.

Subjects

The subjects were 50 professional PIs. Their mean experience was 5.3 years. Eight of them were from IAS, 24 from IEG, 8 from SPAD, and 10 from 25X1 Nineteen of the subjects specialized in ground order-of-battle (GOB) targets.

Experimental Design

Each subject was randomly assigned to one of five groups with the restriction that about the same number of GOB specialists be in each group of 10: the 19 specialists were distributed 4, 4, 4, 4, 3 in the five groups.

The subjects in Groups 1, 2, 3, and 5 viewed three line-scan transparencies and a photographic transparency. The subjects in Group 4 viewed two line-scan transparencies and a photographic transparency. All subjects viewed line-scan transparencies that differed in the number of scans per vehicle but which had the same signal-to-noise ratio. Table 2 shows the experimental design.

TABLE 2
EXPERIMENTAL DESIGN

NUMBER OF SCANS PER TARGET	SIGNAL-TO-NOISE RATIO				
	3	5	10	20	∞
16	G1	G5	G3	G4	G5
32	G1	G2	G3	G4	G5
48	G1	G2	G3	*	G5

*This cell was not represented in the study.

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Procedure

Each subject was seated at a light-table and given a tube-magnifier and a microscope. A set of the 20 model vehicles arrayed in 4 x 5 matrix on a board was placed in convenient view of the subjects. Each model was identified by a number ranging from 1 to 20.

The purpose of the experiment and instructions for the task were explained to the subjects. The instructions were as follows:

1. *Match the images to the models in the order they appear in the transparency proceeding from the upper left-hand corner of the transparency to the lower right. Do not skip any images; respond to them in order.*

2. *Match each image to a model and write the number of the model on your answer sheet.*

3. *Consider each match independently of all other matches. You may match the same model to more than one image.*

4. *Your initial selection is considered as final; do not change your answer unless you get permission to do so.*

5. *Use any magnification you wish.*

6. *Work at your own pace and take breaks when you wish.*

The task was very similar to the frequently occurring operational PI task of identifying military vehicles for the purpose of preparing an order-of-battle report. And, as previously mentioned, attempting to match the target image with the model was similar to the task of matching a target image in an aerial photograph with the target as seen in ground photography or as portrayed in a PI key.

The order of presentation of the transparencies was designed so that, within the restrictions imposed by the number of subjects in each group, the transparencies appeared equally often first, second, third, and fourth. A subject completed the identification task for each transparency before the next one was given to him.

The average time taken to complete the task was about one-and-one-half hours.

RESULTS

The results of the study are shown in Table 3 and Figure 2 for the tank targets and in Table 4 and Figure 3 for the miscellaneous vehicle targets.

Some of the results are immediately apparent. The tanks were more difficult to identify correctly than the miscellaneous targets in both the photographic and the line-scan images. Distinguishing among the tanks is simply a more demanding perceptual task than distinguishing among the miscellaneous targets, because the tanks are very similar in appearance and the miscellaneous vehicles are somewhat heterogeneous.

For both classes of targets, higher percent identification measures were obtained with larger signal-to-noise ratios. For the tank targets, 48 scans per target resulted in higher percent identification measures than 32, and 32 resulted in higher measures than 16. For the miscellaneous targets, 48 and 32 scans per target were better than 16 but there was little difference between 48 and 32.

No effort has been made to smooth the functions shown in Figures 2 and 3 because additional work must be done to obtain the required reliability. Implied in that statement are more targets, more imagery, and more experimental subjects.

The standard deviations given on the bottom half of Tables 3 and 4 reflect the magnitude of the differences in identification performance among the PI subjects. In some cases they were rather large, but as would be expected, with the best resolution line-scan and photographic images, the individual differences were very small.

TABLE 3
MEAN PERCENT CORRECT IDENTIFICATION OF TANKS

NUMBER OF SCANS PER TARGET	SIGNAL-TO-NOISE RATIO				
	3	5	10	20	∞
16	18	20	27	32	56
32	31	38	52	60	83
48	32	43	75	*	98

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VARIABILITY OF PERCENT CORRECT
IDENTIFICATION OF TANKS
(Standard Deviations)

NUMBER OF SCANS PER TARGET	SIGNAL-TO-NOISE RATIO				
	3	5	10	20	∞
16	13	16	15	14	20
32	18	24	20	24	11
48	17	18	23	*	6

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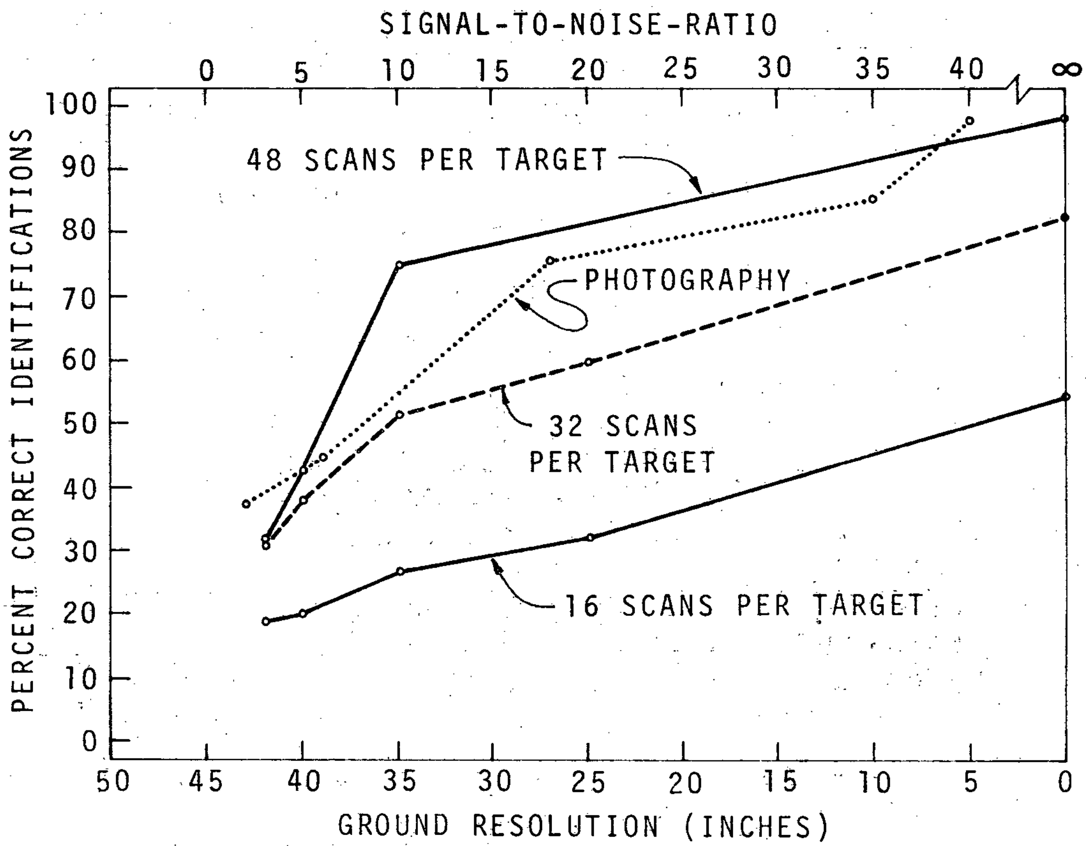


Figure 2. Percent correct identifications as a function of photographic ground resolution and as a function of line-scan signal-to-noise ratio at 16, 32, and 48 scans per target. (Tank Targets)

TABLE 4
MEAN PERCENT CORRECT IDENTIFICATION
OF MISCELLANEOUS TARGETS

NUMBER OF SCANS PER TARGET	SIGNAL-TO-NOISE RATIO				
	3	5	10	20	∞
16	43	44	50	64	83
32	65	59	85	95	100
48	74	79	87	*	98

25X1

VARIABILITY OF PERCENT CORRECT
IDENTIFICATION OF MISCELLANEOUS TARGETS
(Standard Deviations)

NUMBER OF SCANS PER TARGET	SIGNAL-TO-NOISE RATIO				
	3	5	10	20	∞
16	19	20	19	23	20
32	24	23	14	10	0
48	14	14	13	*	6

25X1

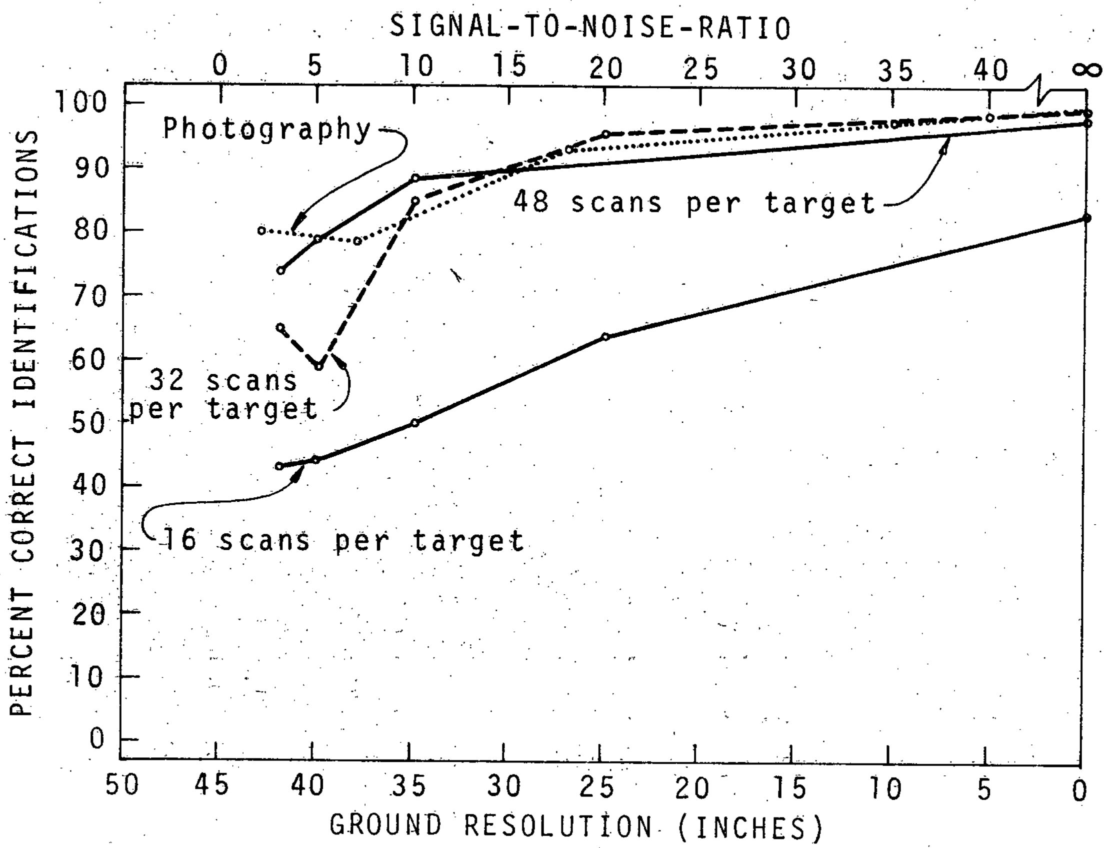


Figure 3. Percent correct identifications as a function of photographic ground resolution and as a function of line-scan signal-to-noise ratio at 16, 32, and 48 scans per target. (Misc. Targets)

Table 5 shows a few of the equivalences in terms of percent correct identifications of tank targets between photographic ground resolution and line-scan image characteristics. The table was prepared to illustrate how data from studies like the one reported here can be used to determine the requirements and specifications of a line-scan system.

The values in Table 5 were obtained from Figure 2 by drawing a horizontal line to intercept the functions at the selected values of Percent Correct Identifications. The values for the four functions were then obtained by reading the top (Signal-to-Noise Ratio) and bottom (Ground Resolution) scales at the intercept points.

An illustration of how the table is read: to obtain 50% correct identifications required 36.5" photography. Comparable performance with line-scan imagery was obtained with 16 scans and a signal-to-noise ratio of 39.5, with 32 scans and a signal-to-noise ratio of 9.5, and with 48 scans and a signal-to-noise ratio of 6.0.

TABLE 5
EQUIVALENCES IN TERMS OF TARGET IDENTIFICATION PERFORMANCE AMONG LINE-SCAN AND PHOTOGRAPHIC IMAGES
(Tank Targets Only)

	IMAGE SPECIFICATIONS		
PERCENT CORRECT IDENTIFICATIONS	16 SCANS/ TARGET	32 SCANS/ TARGET	48 SCANS/ TARGET
50	39.5 S/N*	9.5 S/N	6.0 S/N
60	**	20 S/N	7.6 S/N
70	**	31 S/N	9.3 S/N
80	**	42 S/N	18.0 S/N
90	**	**	32.1 S/N
98	**	**	40.0 S/N

25X1

*Signal-to-noise ratio
**The imagery specified in these cells of the table will not yield the percent correct identifications indicated.

Figures 4 through 9 show the identification performances of the college students used in the 25X1 study and the identification performances of the professional PIs used in the study reported here. As can be seen, the data from the two studies produced similar functions. Because of the magnitude of the individual differences within each group, in no case were the differences between the functions statistically significant. The data do indicate, however, that in novel tasks, such as identifying targets in line-scan imagery, college students perform at least as well as professional PIs.

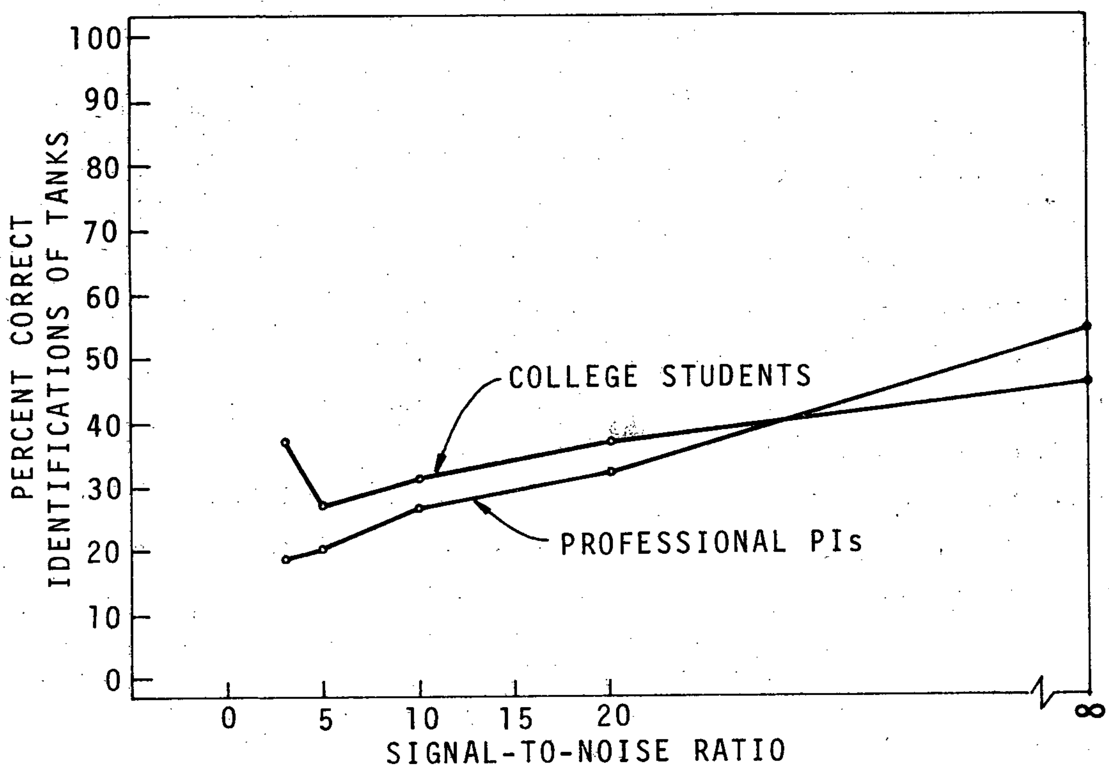


Figure 4. Percent correct identifications as a function of signal-to-noise ratio for 16 scans per target (tank targets). College student and professional PI subjects.

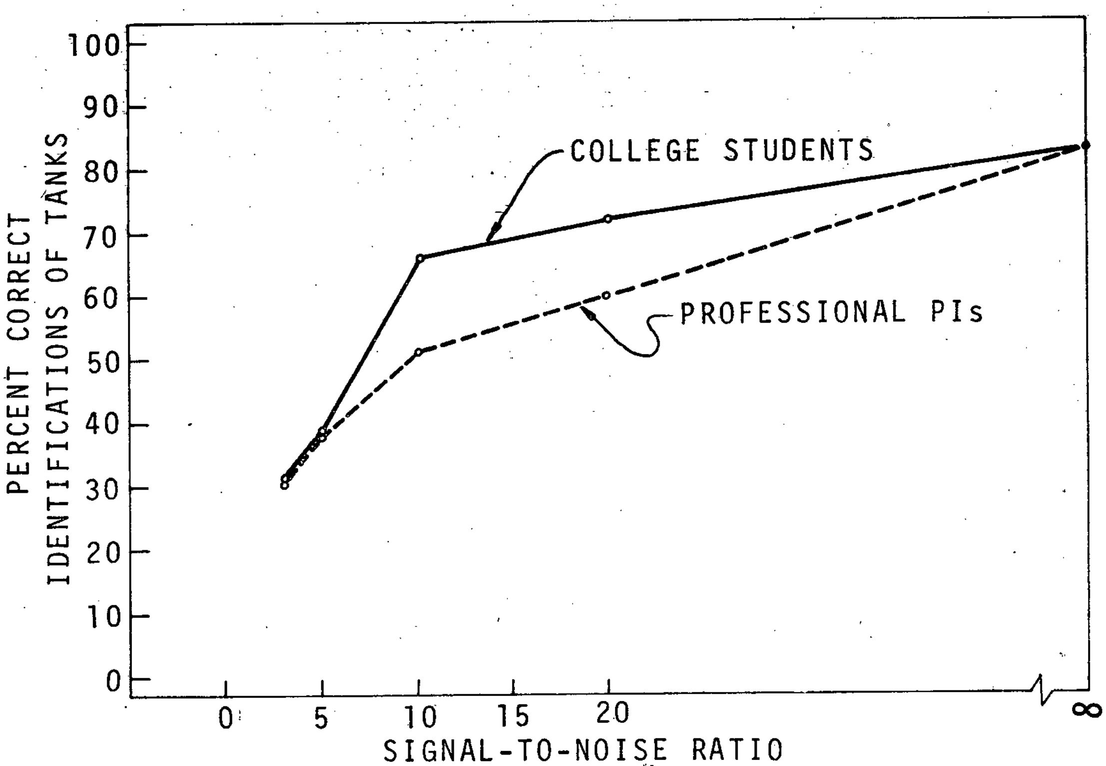


Figure 5. Percent correct identifications as a function of signal-to-noise ratio for 32 scans per target (tank targets). College student and professional PI subjects.

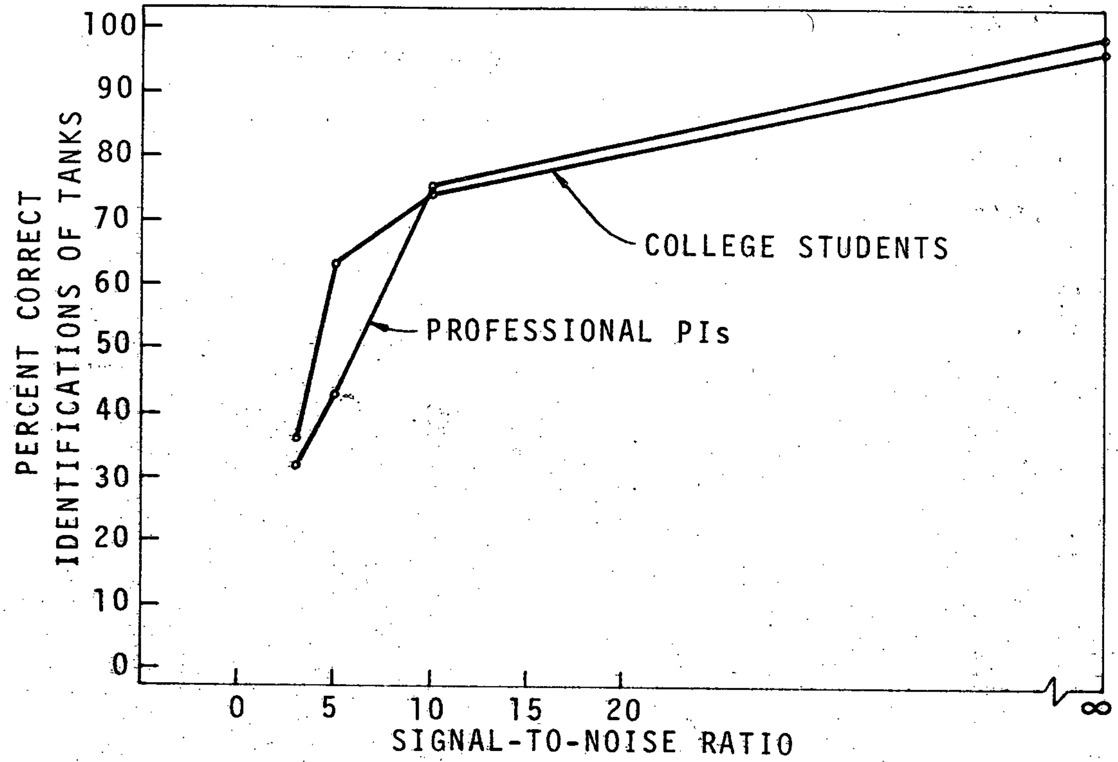


Figure 6. Percent correct identifications as a function of signal-to-noise ratio for 48 scans per target (tank targets). College student and professional PI subjects.

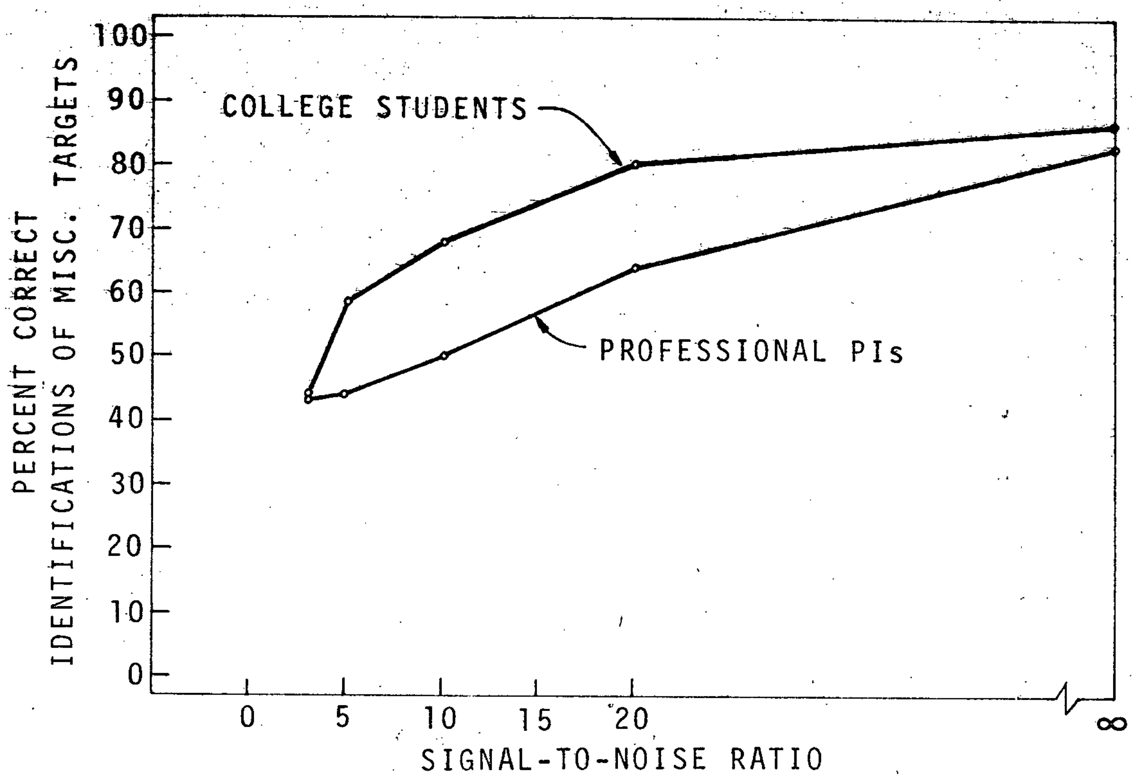


Figure 7. Percent correct identifications as a function of signal-to-noise ratio for 16 scans per target (misc. targets). College student and professional PI subjects.

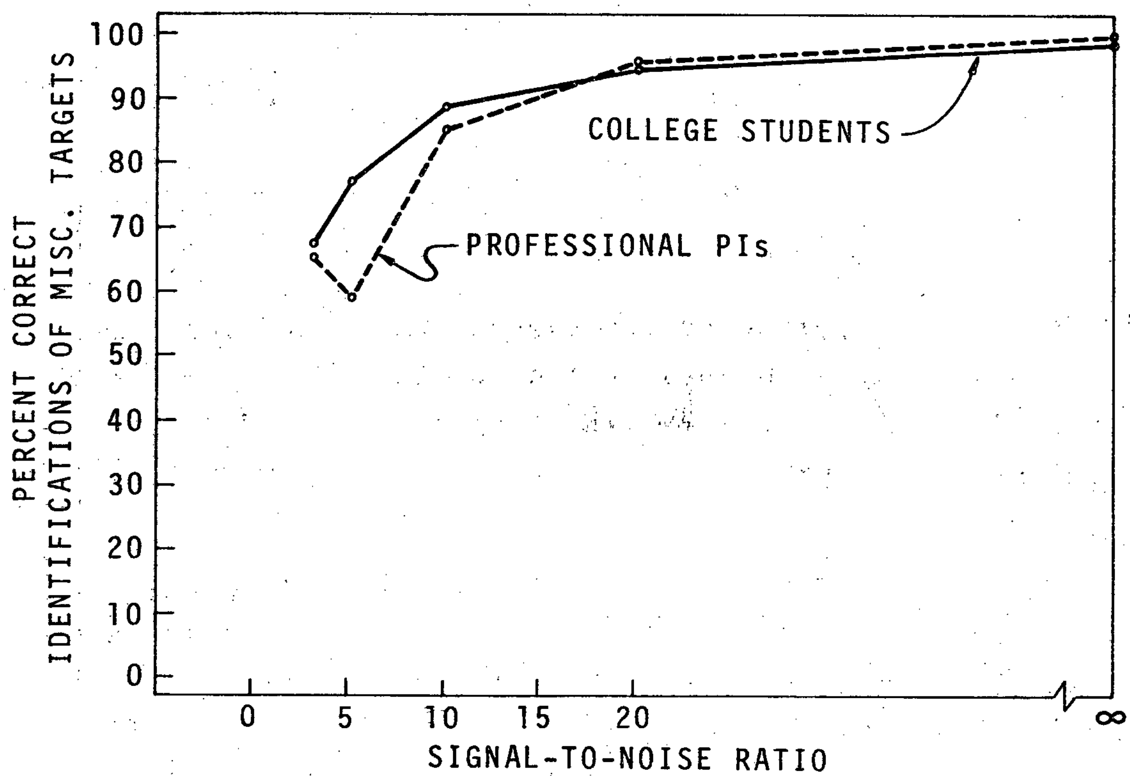


Figure 8. Percent correct identifications as a function of signal-to-noise ratio for 32 scans per target (misc. targets). College student and professional PI subjects.

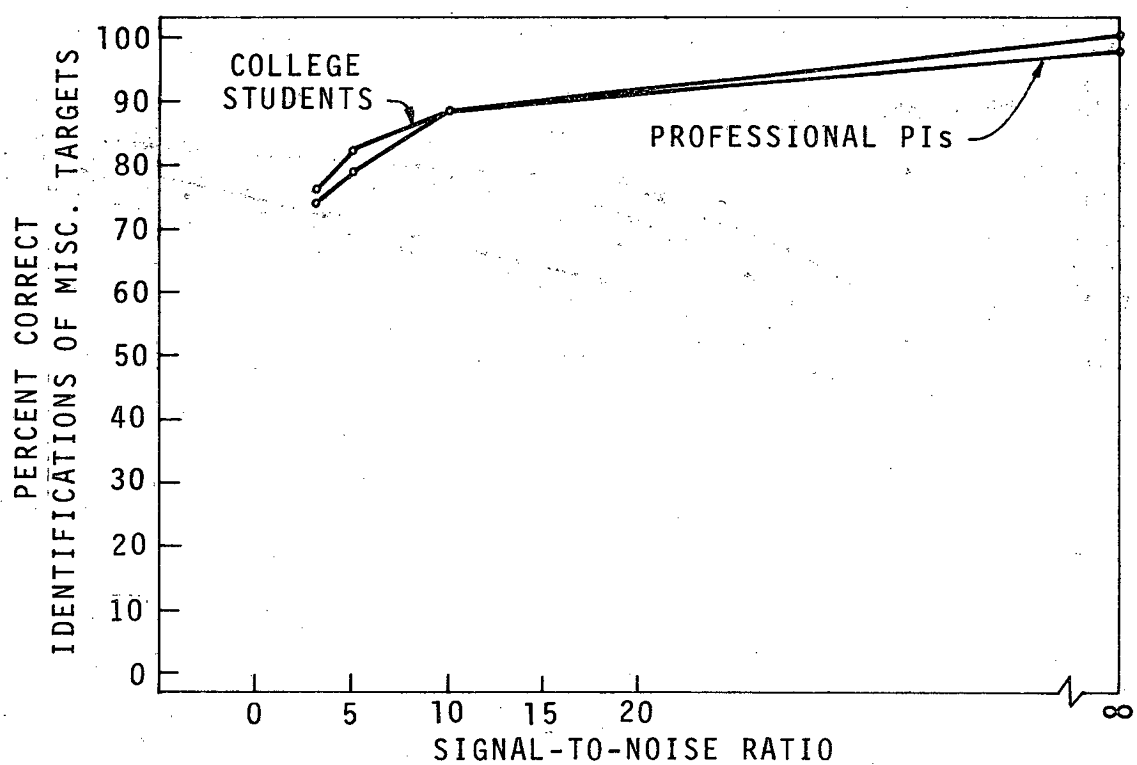


Figure 9. Percent correct identifications as a function of signal-to-noise ratio for 48 scans per target (misc. targets). College student and professional PI subjects.

DISCUSSION

The study reported here was the first effort to determine the relation between line-scan and photographic imagery in terms of photointerpreter target identification performance. The usefulness of the results is limited to the extent that only one sample of targets was used and, among numerous significant line-scan variables, only two were investigated.

On the other hand, a significant first step has been taken. And, because it is obvious line-scan systems are being developed and will eventually be operational, additional steps must be taken so that both collection and exploitation systems can be properly designed. Other types of targets and additional variables should be investigated.

APPENDIX A

A LINE-SCAN IMAGE GENERATOR

Included with permission from the author.

PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 11, Number 5, September–October 1967

A Line-Scan Image Generator

FRANK SCOTT, *The Perkin-Elmer Corp., Research Division, Norwalk, Conn. 06852*

An instrument designed especially for research dealing with line-scan (TV type) images is described. The line-scan image generator (LSIG) transforms a photographic transparency into a line-scan image by electronic, photo-optical, and mechanical means. Its principle of operation is similar to that of facsimile apparatus. The novel features of the instrument make possible the production of line-scan images which exhibit specific and precisely known image structure characteristics. The precise manipulation of the line-scan image characteristics made possible the by LSIG is very commodious in human performance and psychophysical studies, objective line-scan image evaluation, and in exhibiting experimental results of graphical information computer processing techniques. Such research will enhance the design optimization of line-scan imaging systems which are becoming increasingly prominent in aerial reconnaissance and photointerpretation, graphical display, and high-speed data recording.

An instrument was designed especially for research on the informative value of line-scan images. The instrument, or Line-Scan Image Generator (LSIG), transforms a photographic transparency into a line-scan image which can be made to exhibit specific and precisely known image structure characteristics. With the LSIG, sets of line-scan images can be produced in which each picture is identical to every other except for the specific image characteristics selected as variables in experimental designs used in human performance and psychophysical studies. Thus, the instrument is a research tool for investigations on the transfer of information from picture to person.

Experiments dealing with the informative value of pictures require versatility and precise control in the preparation of the stimuli, which, in the case here, are line-scan or sampled images. Among the line-scan image characteristics which can be varied and controlled with the LSIG are the number of scans per picture, the size and shape of scanning spots, the overlap of scans, and the many variations provided by analog and digital electronic processes which include nonlinear treatment of the signal or image-density, spatial frequency filtering, thresholding and isodensitometry, noise addition, quantizing, digitizing, and subsequent computer processing of images.

Description of the Instrument

The LSIG transforms a photographic transparency into a line-scan image by electronic, optical, and mechanical means. Its principle of operation is similar to that of facsimile apparatus, plate-making scanners used in graphic arts, and experimental equipment used by other investigators.[1,2] The instrument, shown in Fig. 1, consists of two similar portions, one of which scans a transparency and the other portion exposes film in a scanning fashion. A small area of a transparency which is mounted on a glass drum is transilluminated while the drum rotates and travels transversely along its axis. Thus, the transparency is scanned in a helical form. By means of a lens, the transilluminated area of the transparency is projected with 10× magnification on a variable transmittance mask which determines the "read-

1. R. N. Wolfe and S. A. Tuccio, *Phoro. Sci. Eng.*, 7: 109(1963).
2. M. C. Stark and L. Cahn, U.S. Naval Training Device Center Report 1-59-1, ASTIA Document 430702, 1964.

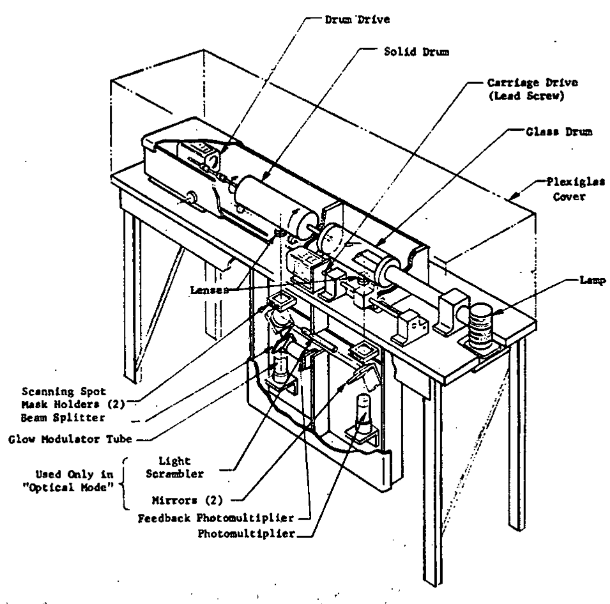


Fig. 1. Line-scan image generator. Electronic equipment not shown.

Presented at the 1967 Annual Conference, May 15, 1967. Received March 15, 1967; revised June 21, 1967.

A-2

ing" spot size and shape with which the transparency is, in effect, scanned. The flux passing through the mask is used directly to expose the film mounted on the solid drum when the instrument is operated in its "optical mode"; the flux transmitted by the mask can also excite a photomultiplier in an "electronic mode" of operation. The other portion of the instrument exposes film on the solid drum with flux which is transmitted by a transilluminated variable transmittance mask at a 10× reduction in size. The mask determines the shape and size of the "writing" spot. When operated in the optical mode, the illumination incident on the writing spot mask is modulated by the flux transmitted by the transparency, the variable transmittance mask, and a light integrator which spatially scrambles the flux. In the electronic mode, a glow modulator tube illuminates the writing spot mask with flux which is linearly or nonlinearly modulated by the photomultiplier output signal and associated circuitry. The light output of the glow modulator tube is monitored by a separate photomultiplier which is part of a feedback circuit.

The two drums are driven with a common shaft by a synchronous motor and gear train at any one of five speeds. The box containing the drums and drum motor travels transversely and parallel to the drum axes past the two scanning systems. The box is driven by a lead screw which is rotated at any of five speeds by a synchronous motor and gear train. Because the drums have a common shaft or axis, and together move transversely, scanning synchronization is thus achieved precisely. The drum and lead screw rotational speed combination and the lead screw pitch make possible the following number of scans (scan lines) per picture:

3.78	82.2	945
8.22	94.5	1890
9.45	189	3780
18.9	378	4720
37.8	472	9450

The maximum transparency size which can be scanned (and hence the maximum line-scan image which can be produced) is 250 × 250 mm. This maximum format size was selected so that the resulting line-scan images can, in most cases, be viewed without magnification and because it is approximately the size of common TV-type displays. The square format makes possible the making of rectangular pictures by using only a portion of the square format; the long side of rectangular pictures can be horizontal or vertical. By mounting the transparency in a specific straight or skewed fashion on the glass drum, the scan lines can be oriented selectively with respect to the image subject.

The time required to scan a maximum size transparency is a function of the transverse speed of the drums and ranges between 3.15 and 158 min. Blue-sensitive film is used in the LSIG allowing the mounting and removal of film under red safelight. While scanning the LSIG can be operated in ambient room light. Color transparencies and color film also can be employed.

Novel Capabilities

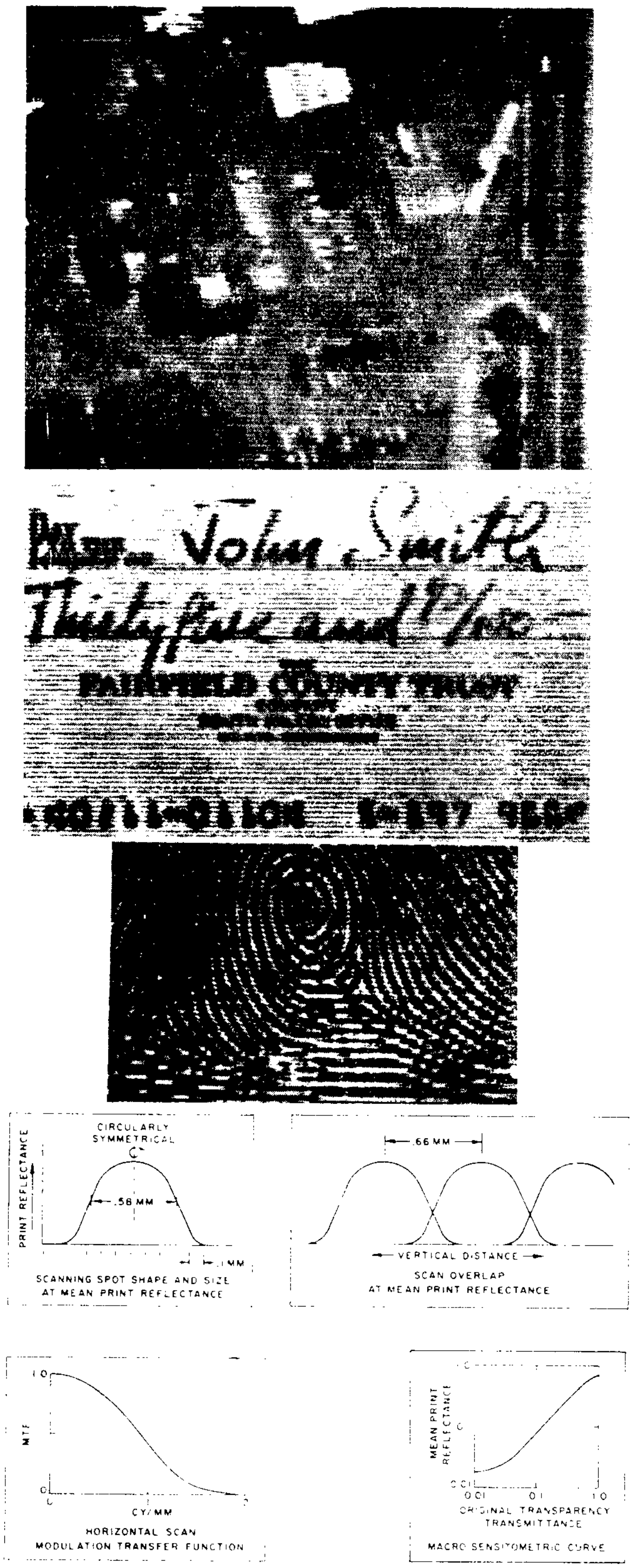
Any two variable transmittance masks can be selected from a library of such masks and inserted in the LSIG to simulate, in effect, the scanning spots of line-scan or television pickup and receiver devices. The two scanning-spot masks used at any one time need not necessarily be identical in shape or size. The maximum vertical dimension of the scanning-spot masks can be such that considerable scan-line overlap is produced. The vertical and horizontal dimensions of the scanning spots can be very small, its minimum useful size being limited by the image-forming capabilities of the optics and the mechanical precision of the LSIG. Accordingly, the horizontal resolution of a frame can be made to vary between 10^2 and 10^4 elements; the vertical element resolution is dictated by the number of scans per frame. Thus, one frame can exhibit from 378 to nearly 10^8 resolution elements. The variable transmittance of the reading and writing spot masks can be circularly nonsymmetrical yielding vertical and horizontal resolutions which are different from one another.

In the electronic mode of operation the photomultiplier output signal can be manipulated in a variety of ways, thus providing the means for signal or information processing. Appropriate circuitry between the photomultiplier and glow modulator tube can provide linear and nonlinear treatment of the image transformation such as frequency filtering, thresholding, quantizing, addition of noise, etc. The photomultiplier output can also be recorded for signal processing and analysis by a computer; the processed signal can then be played back to activate the glow modulator tube. Scanning synchronization, or intentional controlled lack thereof, is achieved during recording/playback by utilization of an encoder mounted on the drum shaft.

Figures 2 to 5* illustrate a few of the many line-scan image characteristics obtainable with the instrument.

The LSIG provides an essential research tool in the study of line-scan images. Its chief feature is the simple and precise control provided in the manipulation of line-scan image structure characteristics. Although it cannot provide a dynamic display its limitations are not bound by performance factors inherent in an all-electronic system such as phosphor characteristics, electron optics and ballistics, circuit complexity, difficulty of image characteristic measurements, etc. The instrument has proven to be very useful and continued use of the LSIG will, no doubt, suggest desired modifications and applications which will extend its utility.

* Figures 2 to 5 appear on the next two pages (pages 350 and 351).



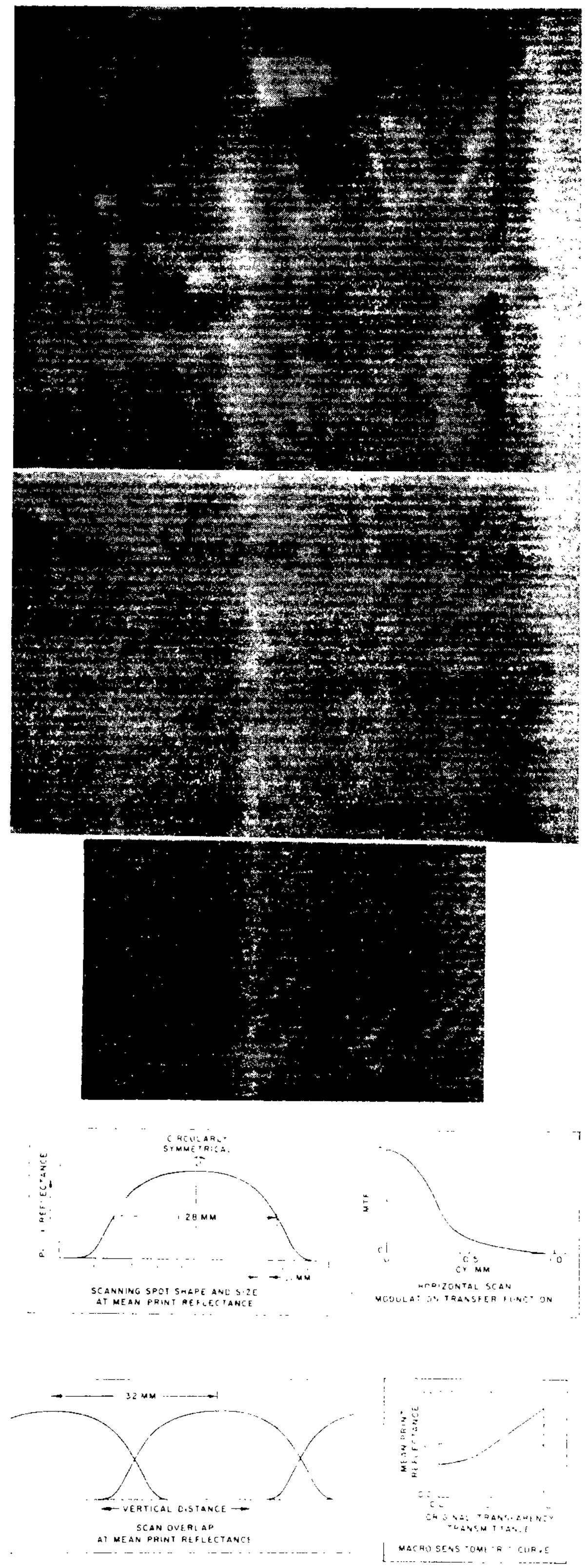
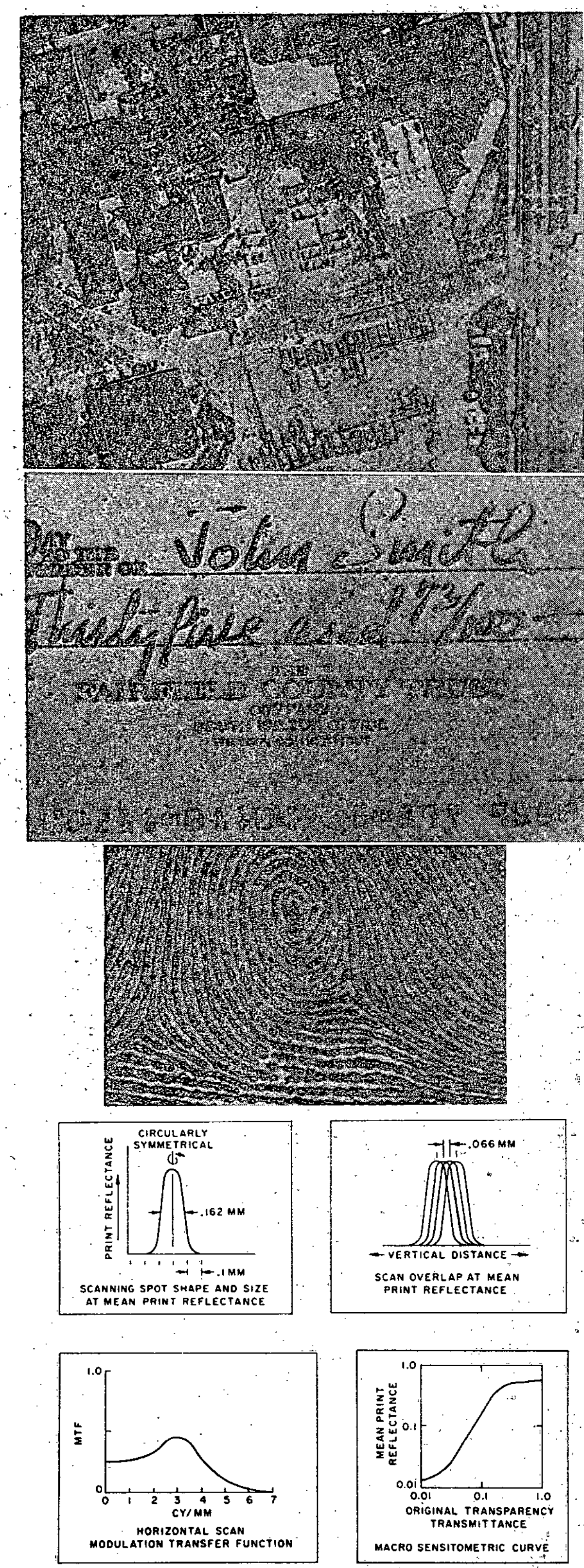


Fig. 2. Line-scan image made with LSIG in optical mode. 1.50 scans per mm.
Fig. 3. Line-scan image made with LSIG in optical mode. 0.76 scans per mm.



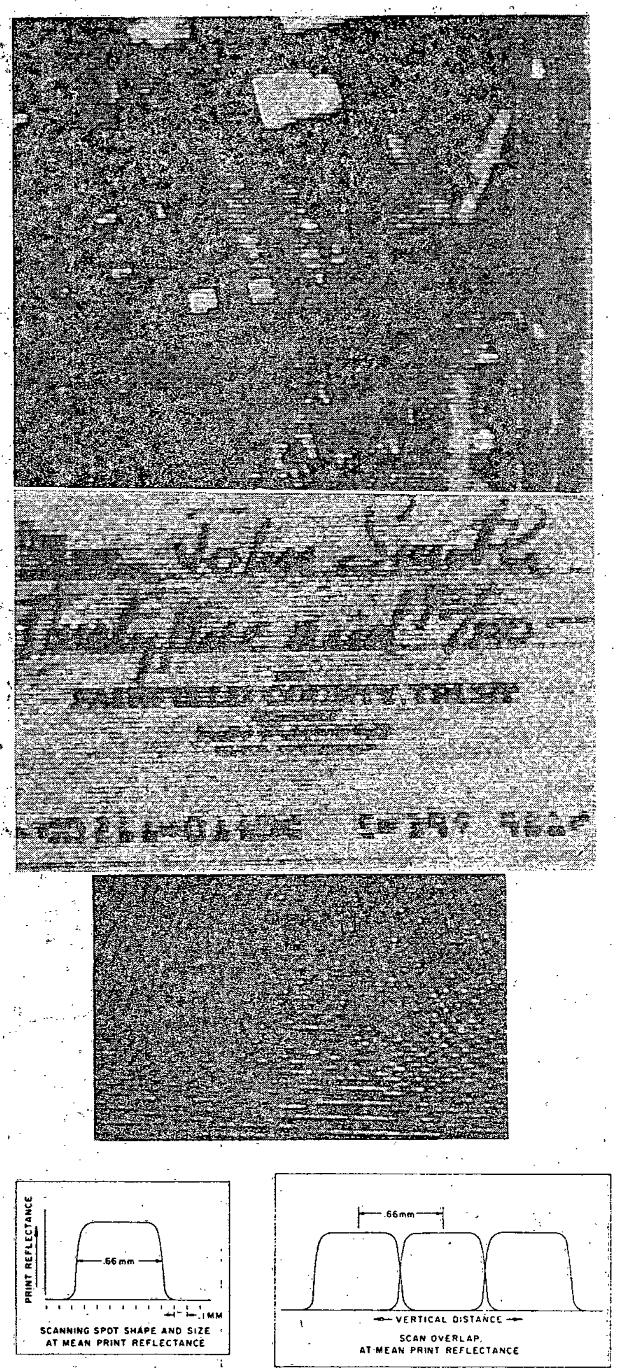


Fig. 4. Line-scan image made with LSIG in electronic mode illustrating low spatial-frequency attenuation. 1.50 scans per mm.

Fig. 5. Line-scan image made with LSIG in electronic mode. Gaussian noise added. 1.5 scans per mm.

APPENDIX A (Continued)

THE DIGITAL TAPE MEMORY SYSTEM

SECTION I

INTRODUCTION

This report describes the instrumentation for digital data acquisition and processing of the Line-Scan Image Generator (LSIG) analog signals.

The digital equipment is in "series" with the present analog circuitry of the LSIG so that information can be handled in either an analog or digital mode. The choice of mode is accomplished easily and efficiently by the operator.

SECTION II

GENERAL DESCRIPTION

2-1. SYSTEM COMPONENTS

The overall instrumentation will be referred to as the Digital Tape Memory System (DTMS). The system consists of the following major components:

a. Data 620/i computer
b. Analog to digital converter
c. Magnetic tape transport
d. Digital to analog converter
e. Digital shaft encoder
f. Special logic, interfaces and controllers

A more detailed description of the major components is contained in the following paragraphs and in the Appendices.

2-2. 620/i COMPUTER

The Data 620/i consists of a data processor and a core memory. The data processor controls the acquisition, routing, timing, and handling of the data. It acts as the central controller of the system. All data passes through the processor on either recording or playing back the digital information. Physically the processor consists of digital integrated circuit gates and flip-flops, which are

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Reprinted with permission from the authors: [redacted] 25X1
[redacted] *Informative value of dynamic images as a function of signal and noise characteristics*, Phase 1, Task 2. [redacted] Report No. 9226, May, 1968. 25X1 25X1

mounted on printed circuit cards. The core memory is the buffer storage, which actually holds all the digital data being written or read off the magnetic tape, and the stored program for operation of the system. The core capacity is 4096 16-bit words, which represents the maximum content of one scan line of the stored original image.

2-3. ANALOG TO DIGITAL CONVERTER

The Analog to Digital Converter (ADC) is an electronic device which changes an input analog signal voltage to a digital number. For the full scale range of input voltage, an increasing voltage is converted linearly to an ascending binary number as shown in the following table:

Typical Format of Conversion

Analog Input (Increasing Voltage)	Digital Output*
+ 0.00 volts	0 0 0 0 0 0 0 0
+ 2.50 volts	1 0 0 0 0 0 0 0
+ 5.00 volts	1 1 1 1 1 1 1 1

*increasing binary number

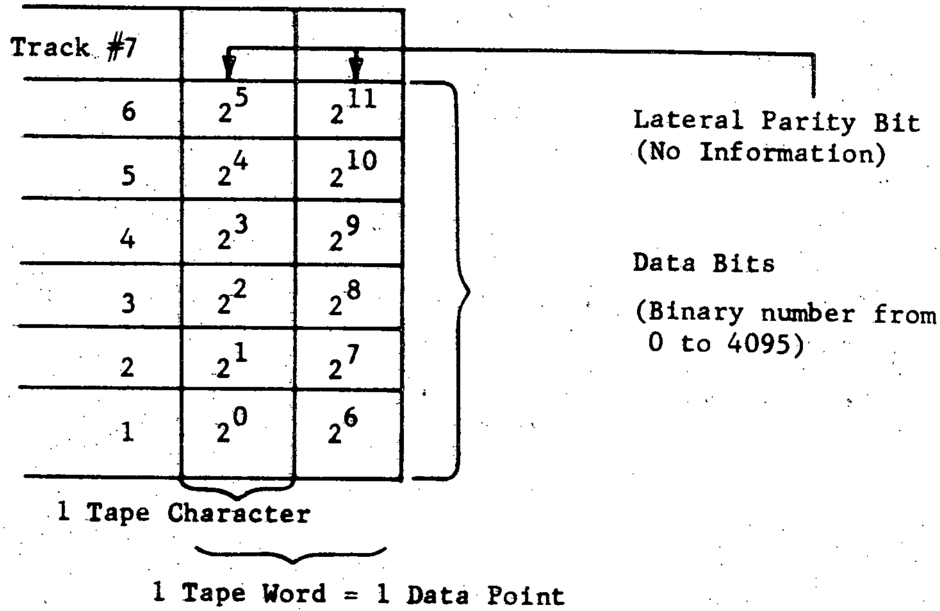
In this system the ADC accepts a full scale input range of 5 volts and produces a 12-bit digital output.

2-4. DIGITAL TO ANALOG CONVERTER

The Digital to Analog Converter is similar in function to the ADC, except that it reverses the process and converts a binary number into a proportional analog signal voltage.

2-5. TAPE TRANSPORT

The magnetic tape transport is an Ampex Model TM-7 tape drive. It consists of motors, mechanical assemblies, and the electronics required to move the tape synchronously and either record or read back information. The tape that is produced is 7-track standard IBM compatible tape. Data is formated in natural binary in the following way:



2-6. DIGITAL SHAFT ENCODER

As the LSIG central shaft rotates, it couples to and directly drives the encoder shaft. The shaft rotates a disc that has equally spaced, alternate transparent and opaque areas on its circumference. Light from a small lamp is directed at 90 degrees to the disc rim. The absence or presence of light is then detected by a photodiode as the shaft turns. The photodiode two-state output is then converted to a serial electronic pulse train.

SECTION III

SYSTEM OPERATION

The operation of the DTMS is described with references to the block diagram of Figure 1.

3-1. RECORDING

In the Record Mode, the encoder converts the geometric shaft position (circumferential angle) of the target image to an electronic pulse train. This pulse train is counted for each revolution. A switch selects the number of equally spaced samples of photomultiplier voltage to be digitized per rotation (i.e., to represent that "line" of the scanned image). The Analog to Digital Converter provides a parallel 12-bit digital representation of the instantaneous values of photomultiplier voltages. Each conversion thus becomes one data point or word for computer processing. The analog to digital converter signals the computer that a particular conversion has been completed.

At this time, the computer accepts this word and stores it in a program-designated location in its core memory. When the selected number of words representing a scan line are acquired, the computer indicates that a "record" is finished. The record is then transferred to the magnetic tape controller. The controller prepares the data for the tape transport and directs it to start, run, or stop, as required; thus, the entire record is written on a block of tape. This process is now iterated until the entire transparency has been scanned. This results in a "file" of tape being produced.

3-2. PLAYBACK (See Figure 2)

After the transparency has been digitized and stored on the magnetic tape, it can be played back and a new line-scan image produced. If desired, the recorded tape can be processed on a more powerful computer and various algorithms performed on the data. The output of this process is a new "edited" reel of tape, which can be used to create line-scan images exhibiting precisely controlled image-structure characteristics.

In the playback mode, each record of data is read from the tape and stored in the core memory of the computer. Thus, the full information for one line or revolution is available in a buffer prior to its use. As the encoder detects each desired geometric shaft address, the proper data point is selected from core memory by the program. This selected word is then transferred to update the output of the digital to analog converter. The digital to analog converter accepts this digital data and provides an analog voltage output that is proportional to the numerical binary value of the input. The output voltage now is used to modulate the light output of a glow tube. This light exposes a photographic film. The entire process is repeated for each stored line of the original target. Thus, the final output is an image, which is a line scanned representation of the original.

SECTION IV

CAPABILITIES

The DTMS fulfills the required task of digital data handling of the LSIG analog signals. In addition, it has the capability of experimentally varying the following parameters.

a. Number of bits (most significant digits of A-D Conversion) of (gray-scale) resolution of the individual data points or words.

b. Number of data points per record or line.

c. Number of records per file.

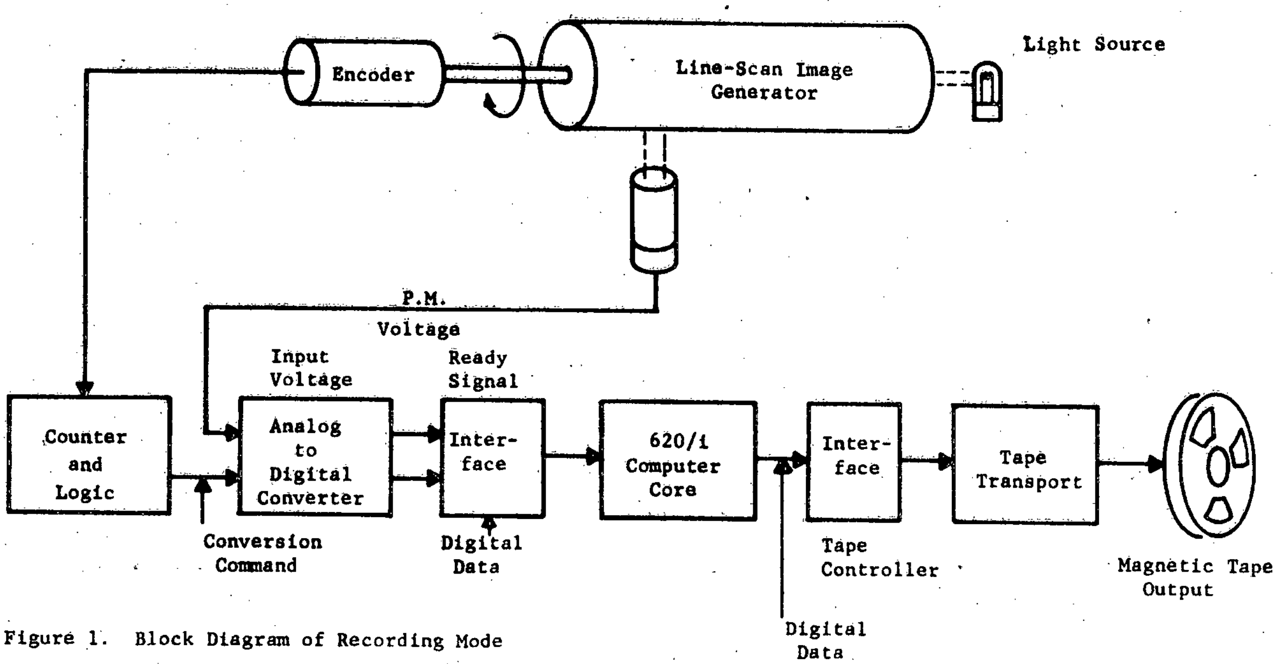


Figure 1. Block Diagram of Recording Mode

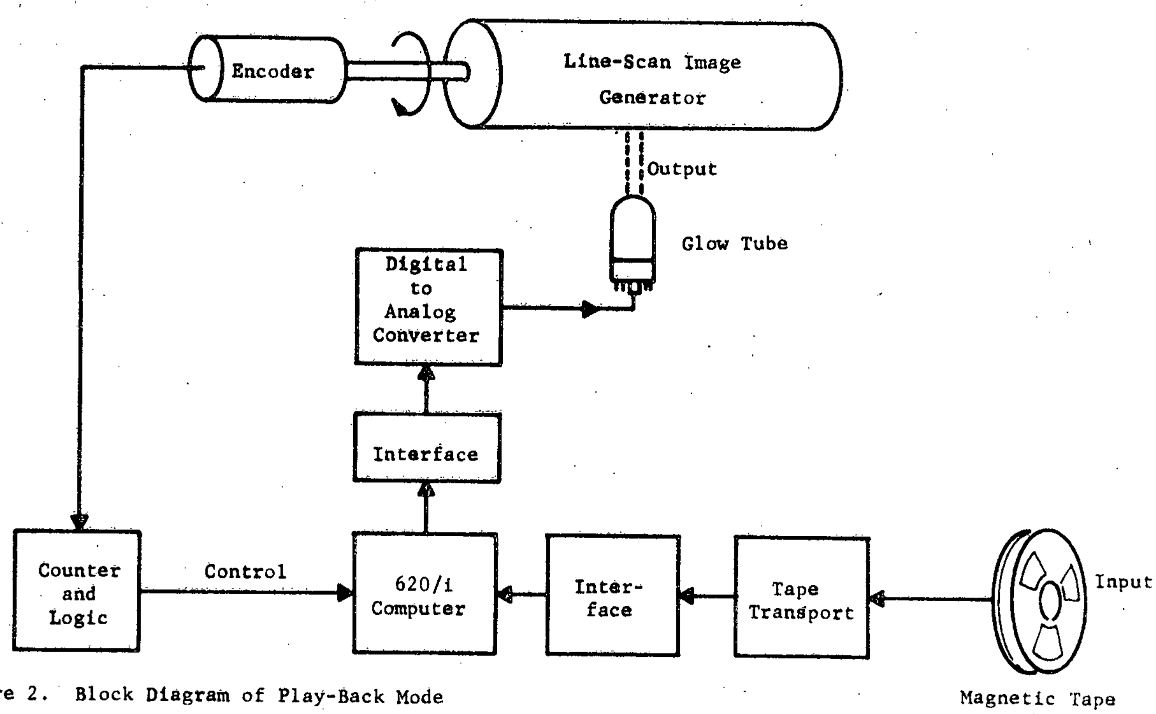


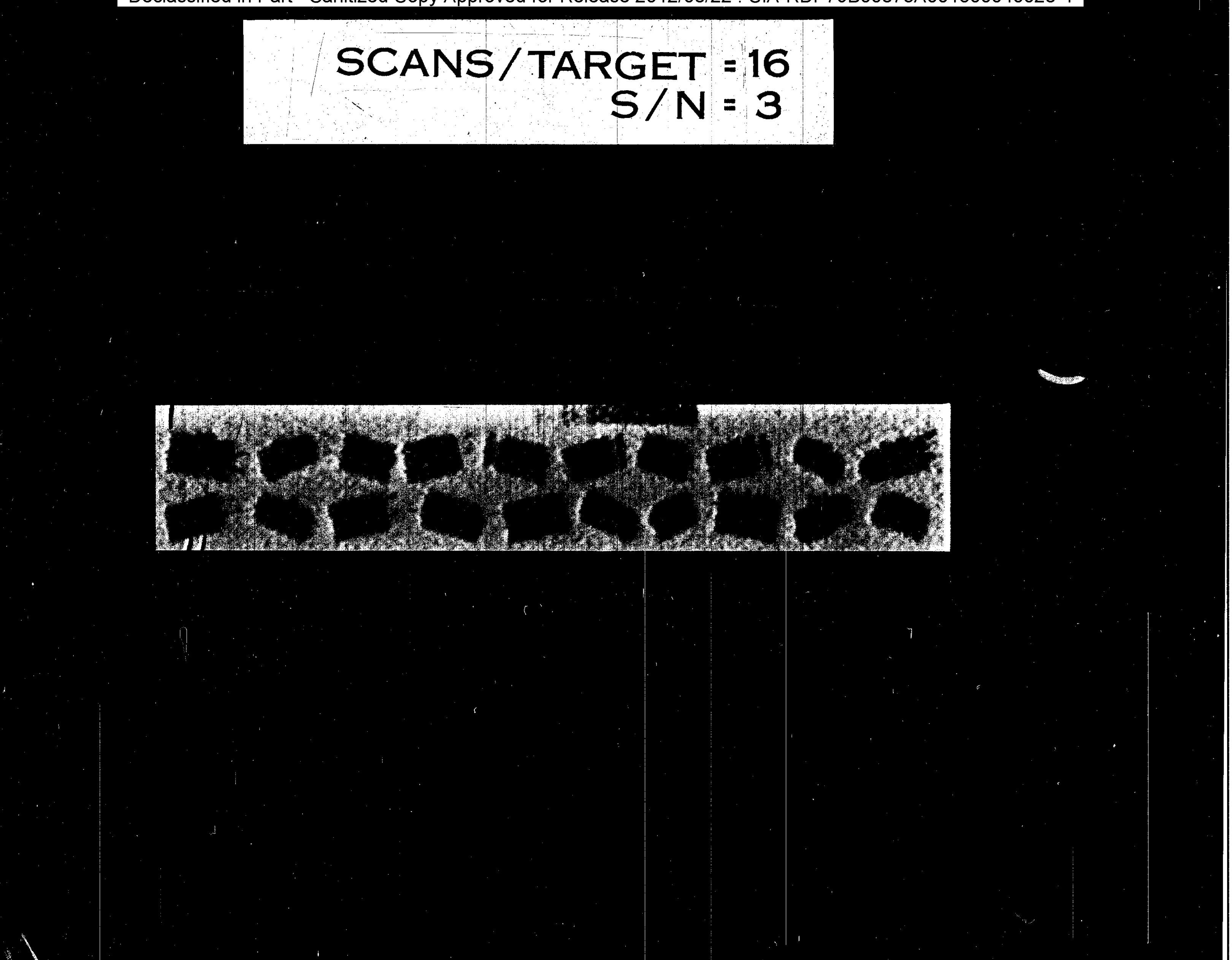
Figure 2. Block Diagram of Play-Back Mode

GLOSSARY OF TERMS

Bit	- An ordered position in a word (e.g., 2^2 place).
Buffer	- A digital storage device (e.g., the core memory of the 620/i computer).
Data Point or Word	- A single digital number of value representing an elementary sampled area. The smallest spatial resolution element of the image.
File	- M Records representing the entire image.
Program	- A fixed set of instructions to the computer that control the desired process.
Record	- N words representing a complete line of the image.
Tape Character	- A lateral group of 6 Bits across the magnetic tape.
Tape Word	- Two Tape Characters that constitute a word.

APPENDIX B

THE LINE-SCAN IMAGERY



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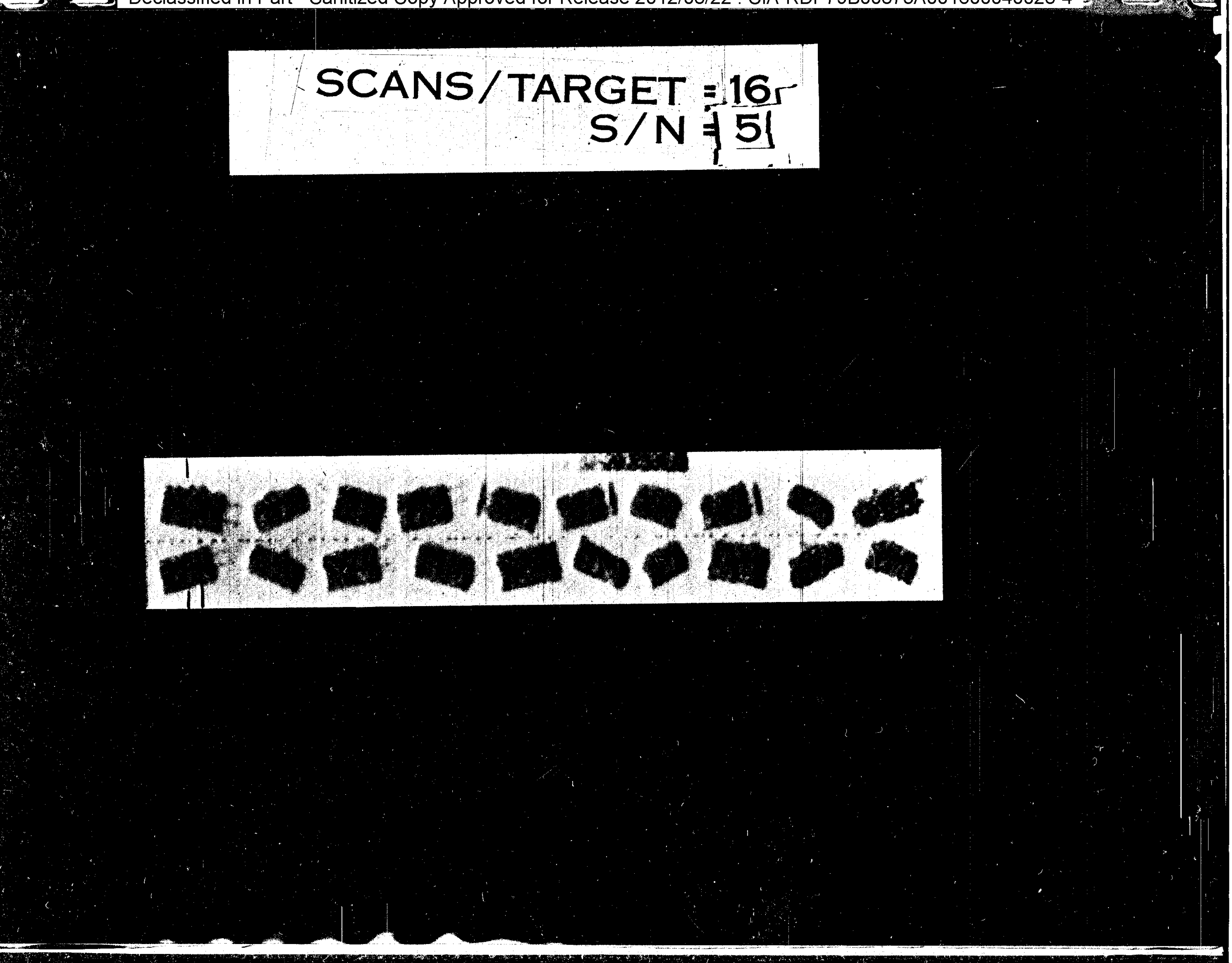

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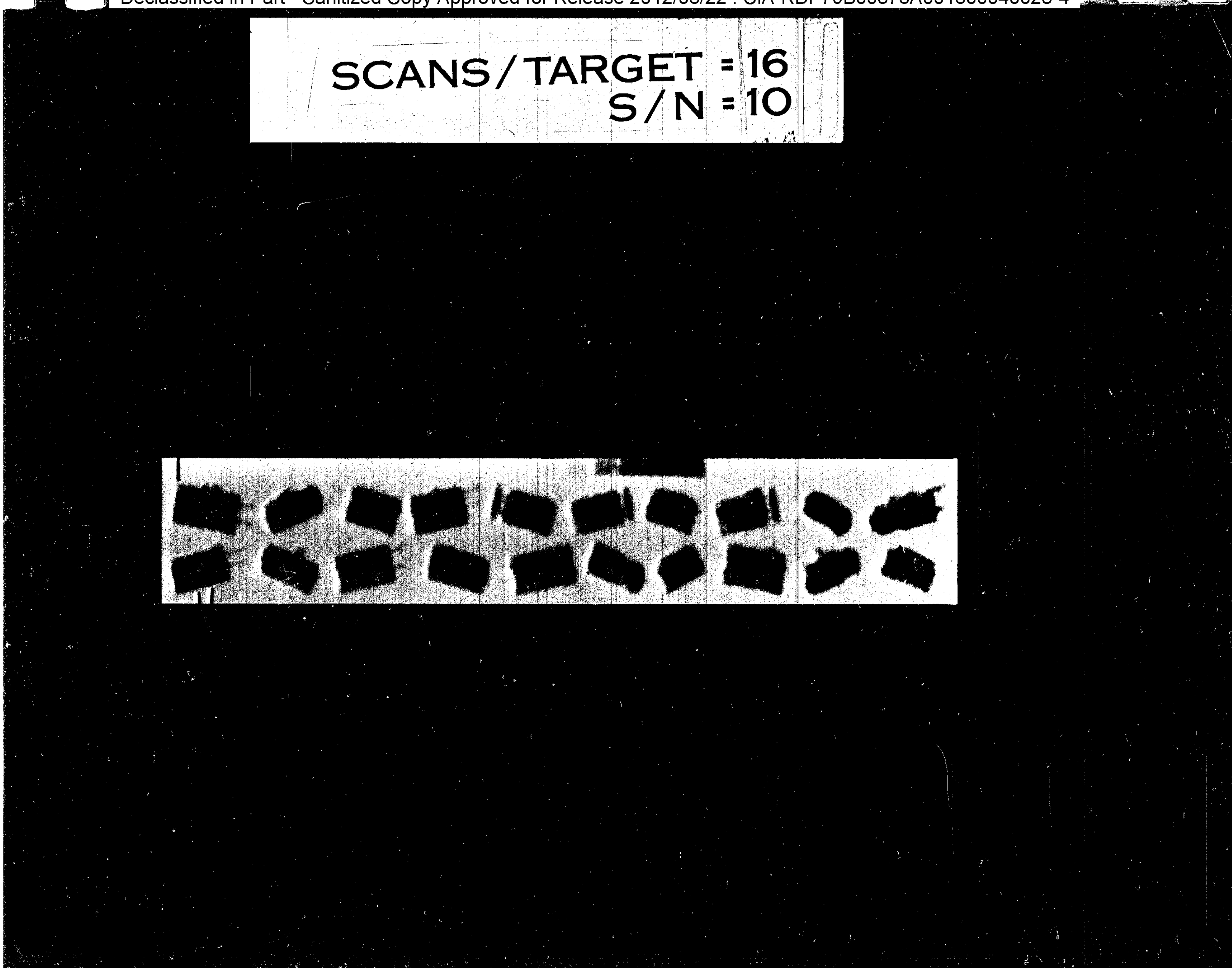

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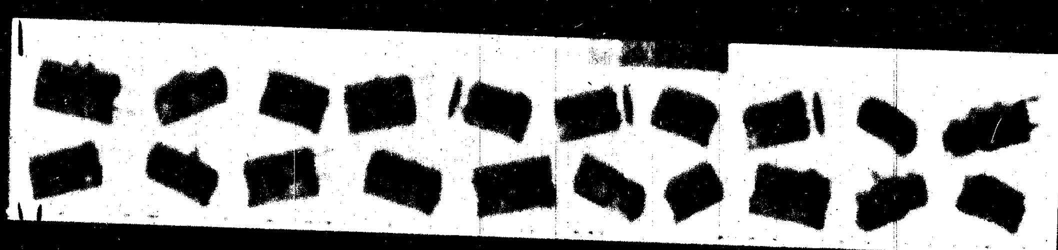
S/N = 20



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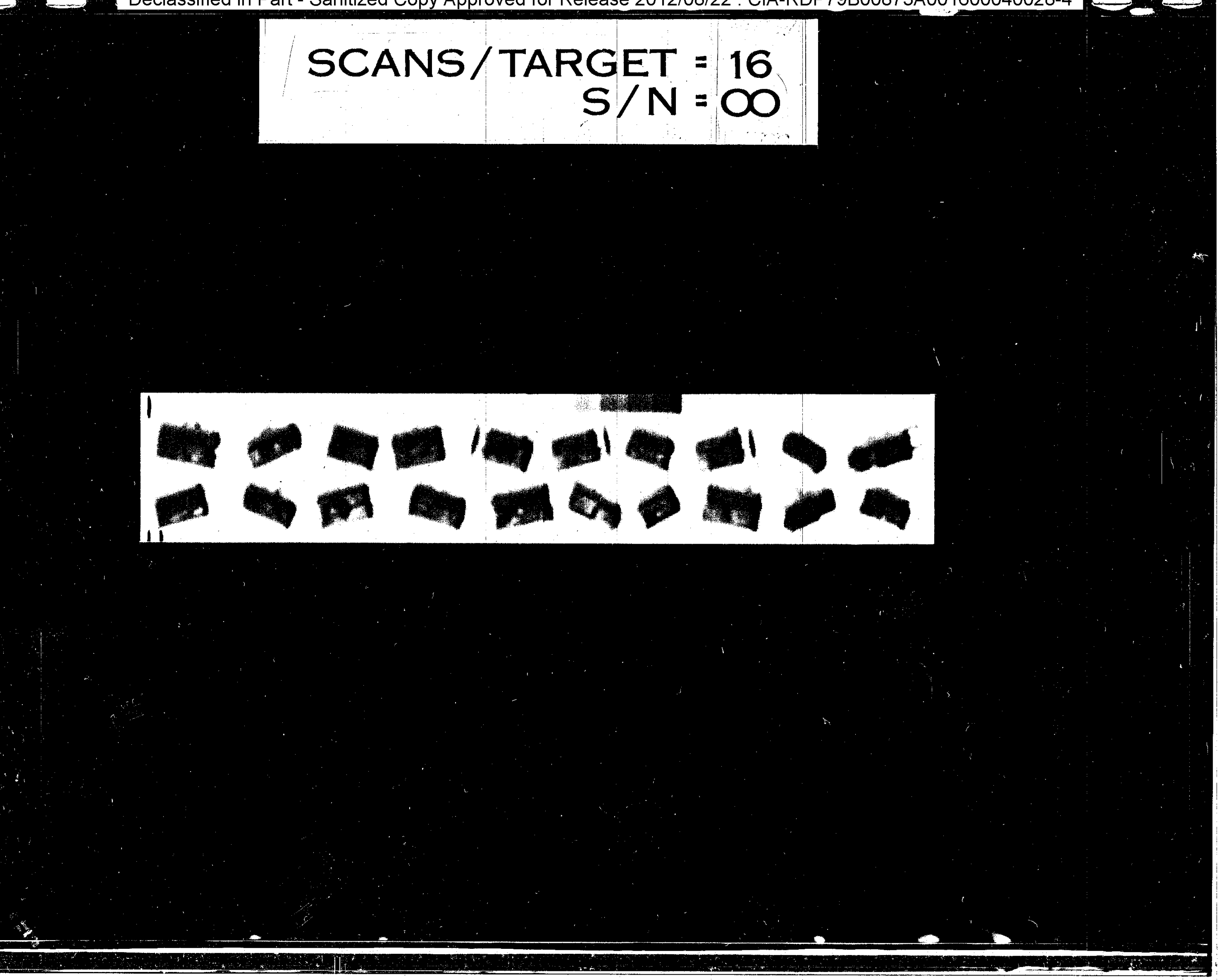
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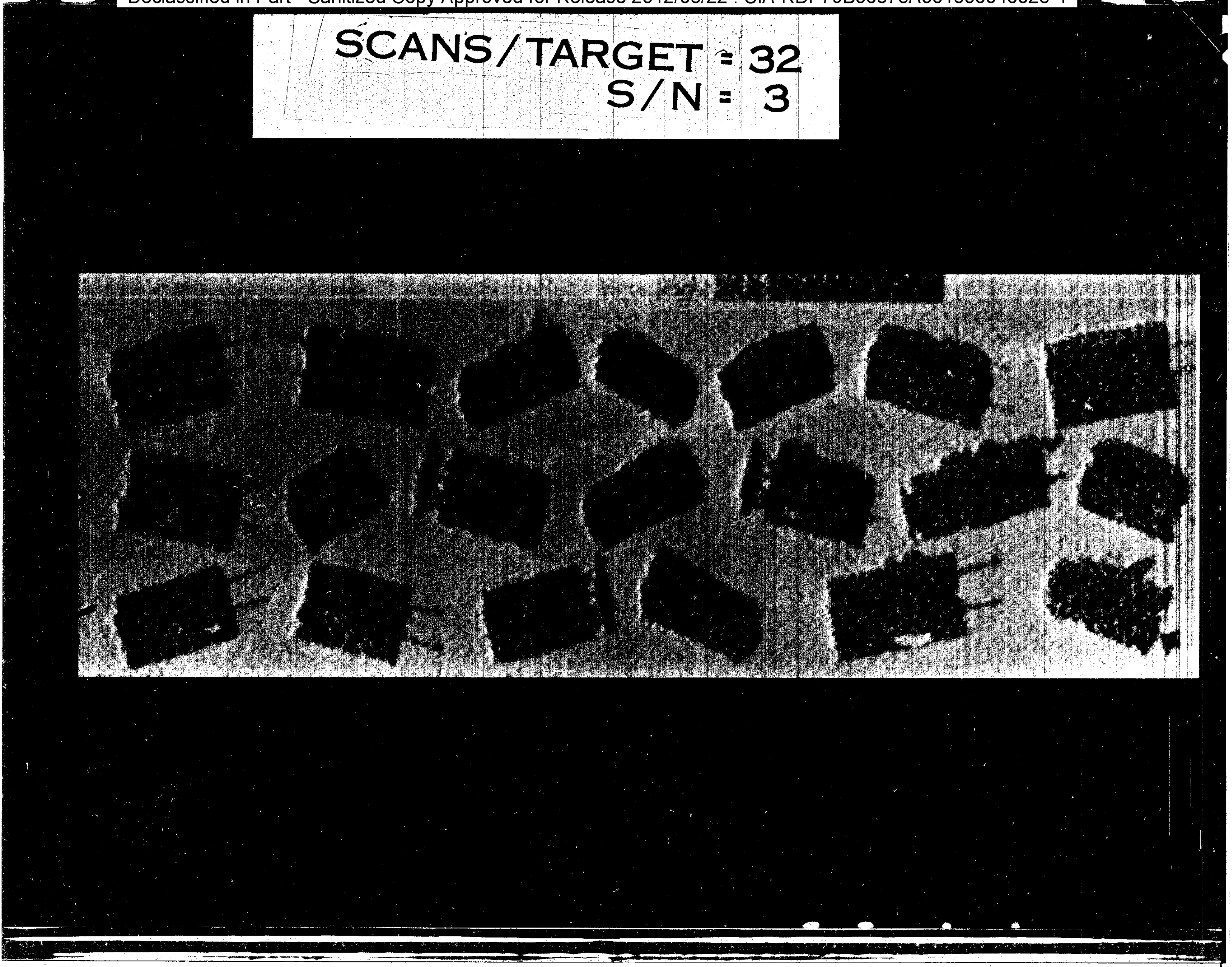
S/N = ∞



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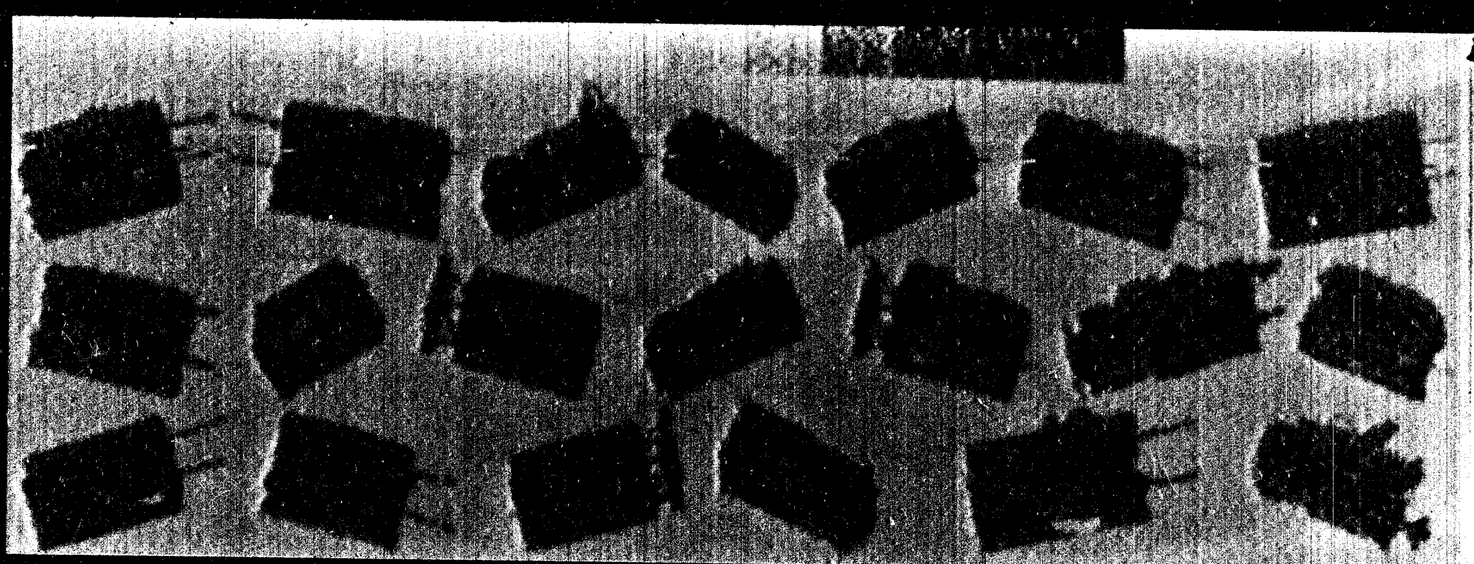

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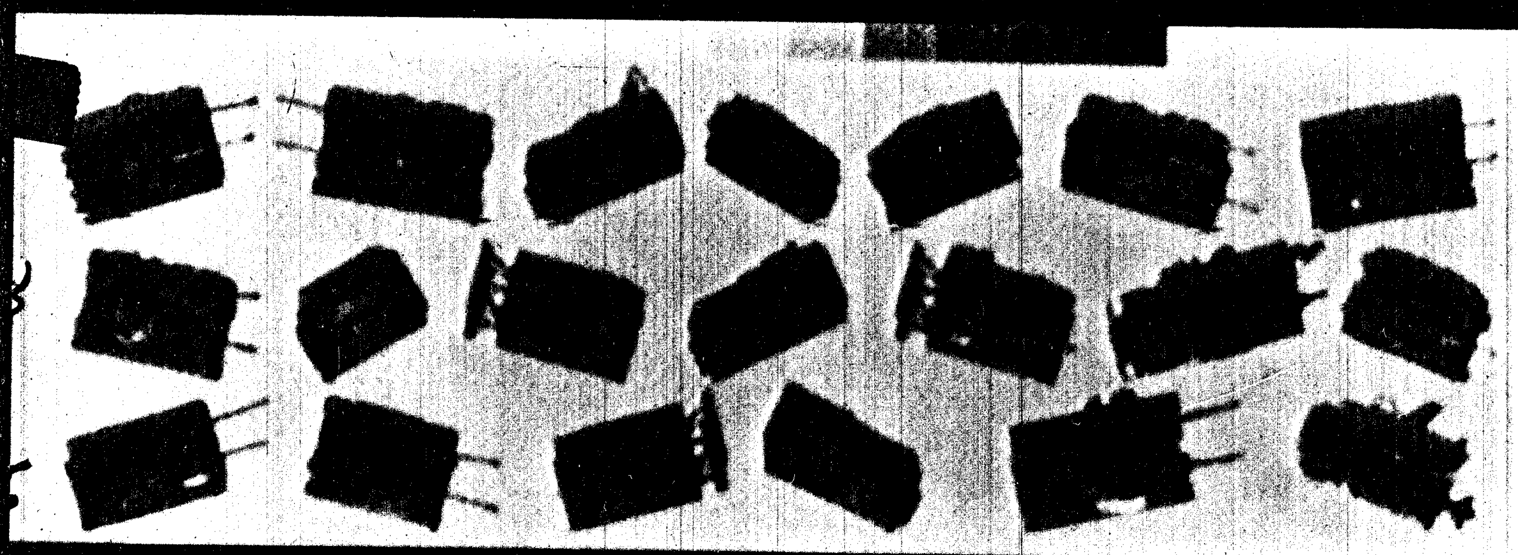
SCANS/TARGET = 32
S/N = 10



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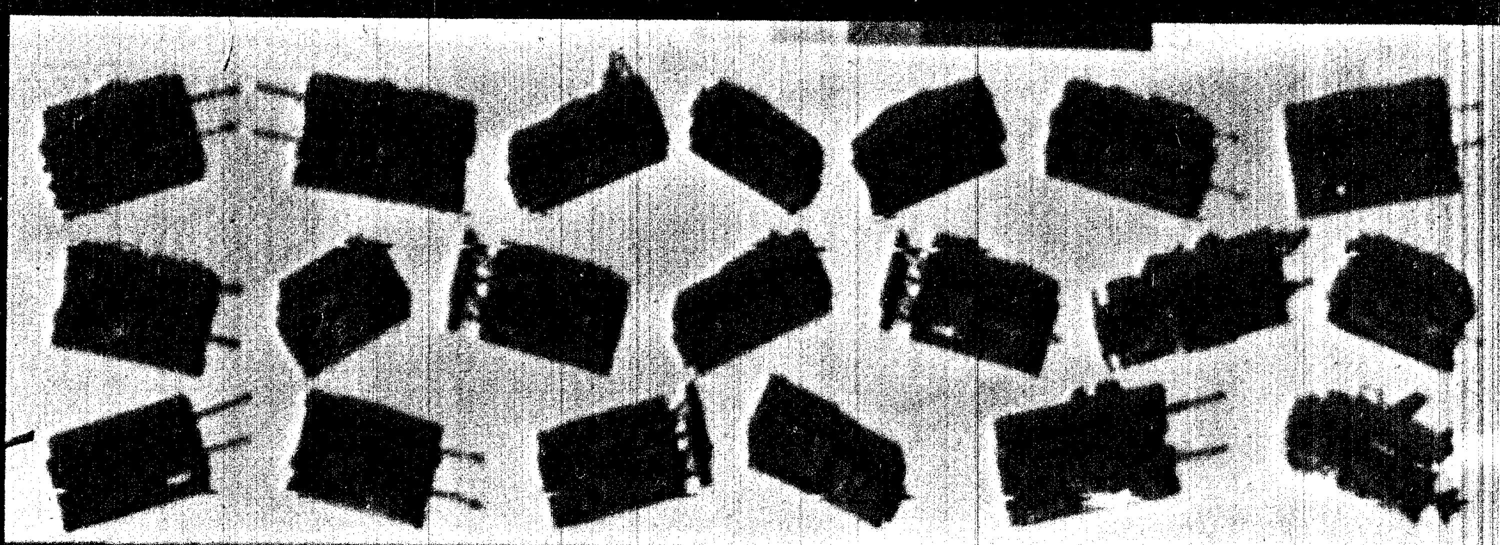
S/N = 20



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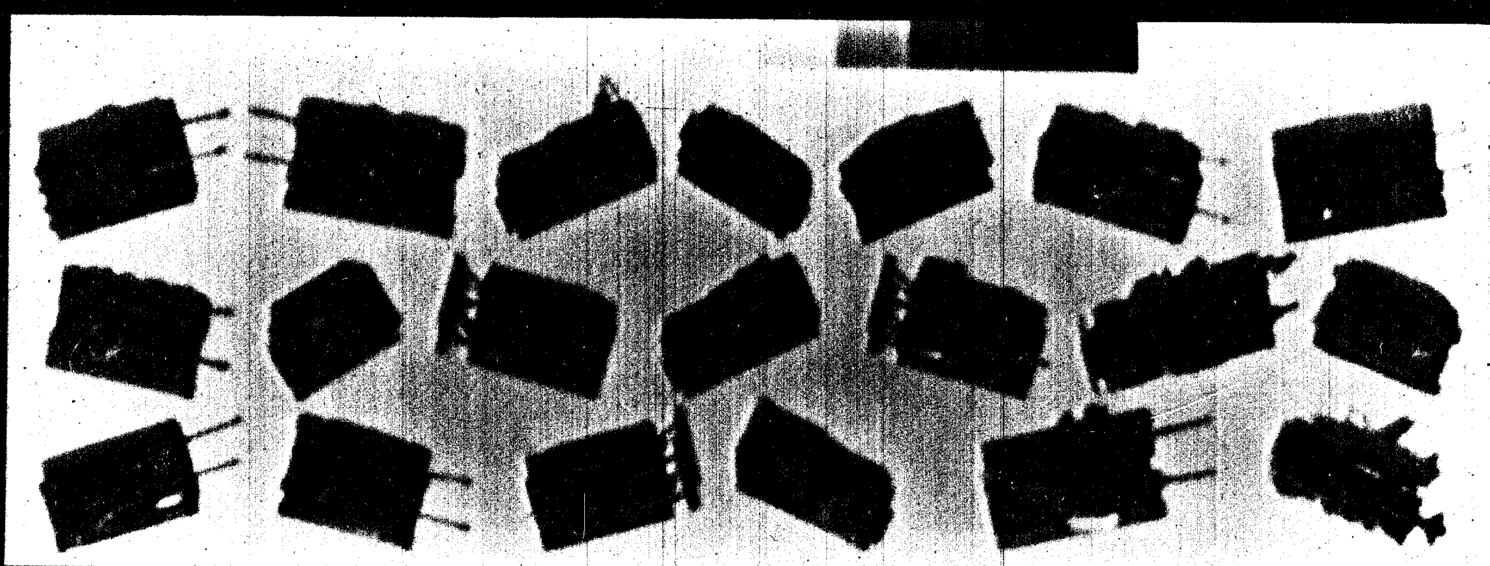
S/N = ∞



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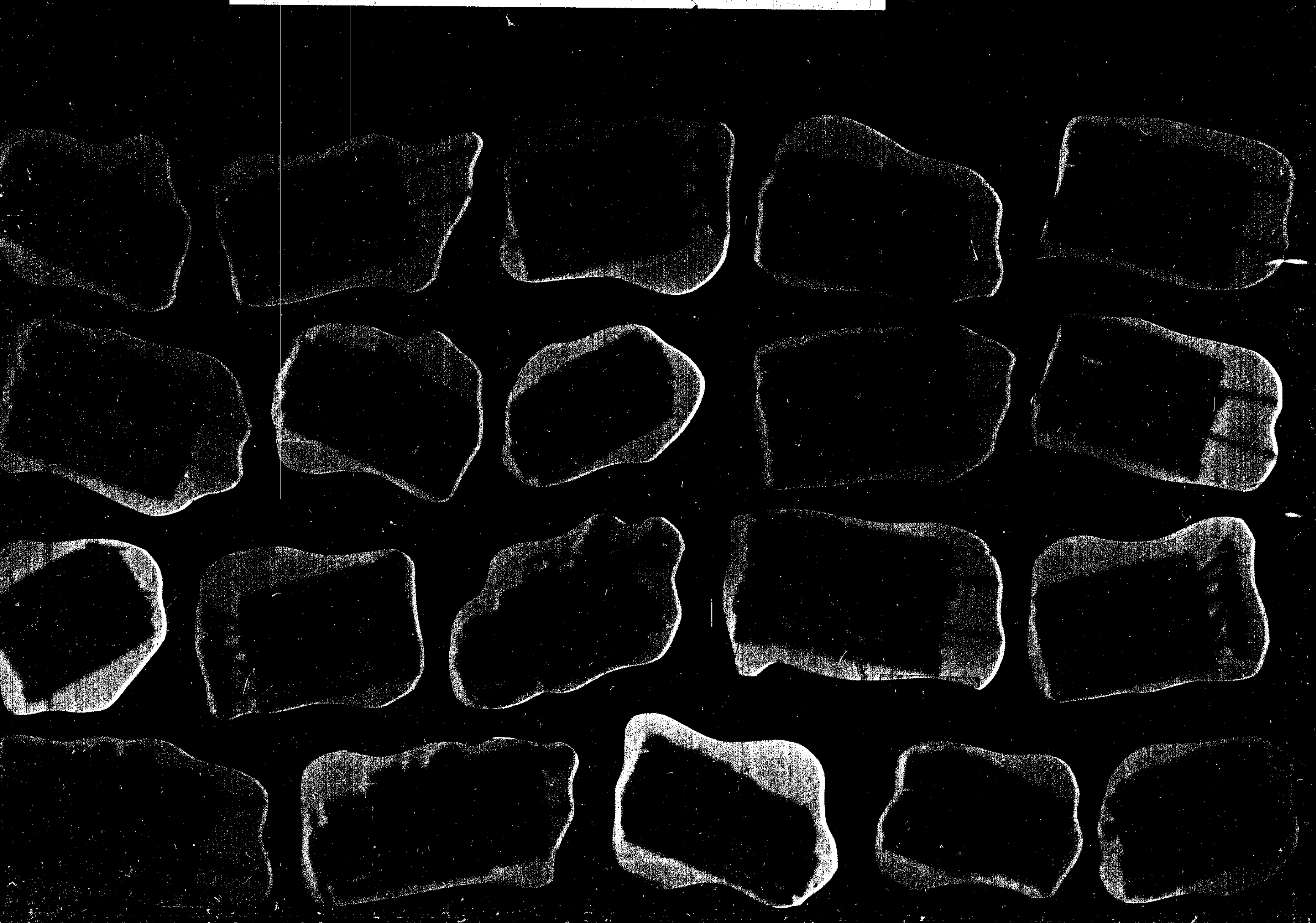
SCANS/TARGET = 48
S/N = 3

SCANS/TARGET = 48
S/N = 5

SCANS/TARGET = 48
S/N = 10



SCANS/TARGET = 48
S/N = ∞

APPENDIX C

VEHICLE GEM SET

SPO 28919

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July 1969

A set of positive GEM photographs was generated by photographing a negative original with controlled degradation in a 1:1 optical system. The degradations were achieved by defocusing the optical system. The resulting GEMs frequency spectra are shown in Figure 2. The frequency spectra of the GEMs was measured by scanning edges in the scene with a microdensitometer and processing the data with a form of edge gradient analysis. A GEM master negative was not required as the original negative supplied had a gamma of 1.0.

The choice of an optical system for the generation of the GEMs was based on the ease this method affords for controlled image degradation and by the time and cost limits imposed on this program. A 1:1 camera system was set up on an optical bench and consisted of a 105mm Schneider Componon lens, target holder and film back. Defocusing was achieved by movement of the film back away from the target holder by a micrometer stage adjustment. The original negative's frequency spectra did not contain high frequency information as is shown in Figure 1. This MTF curve was determined by scanning several edges throughout the original negative frame format and selecting a transfer function that was the approximate center of the data spread. Thus phase shifts caused by defocusing was not a problem, due to the nature of the original scene. Tri-bar resolution was used to determine the positions of the film back which gave resolutions of approximately 1/2, 1/4, 1/8, and 1/16 of that obtained at the prime focal position. These positions were then used to photograph the scenes, along with a target array which consisted of an edge, high and low contrast tri-bar targets. The addition of these targets was made necessary by the large amounts of defocus used. Measurements of edges within the scene could not be made for cases of low resolution due to the large area required to properly measure the edges. The density differences of the edge and background in the target array were selected to nearly match the density differences in the scene. Listed in Table 1 are the density values for the GEMs and the reference target array. Density measurements were made on vehicles in the four corners and in the center of the scene. The results of measurements made on the test target control edges appear in Figure 2. Traces of reference edges contained in the scenes for which it was possible to measure the edges (number 0, 1, and 2) are given in Figure 3. The image for the remaining GEMs could not be traced due to problem of the scan length required. The data given in both these figures is uncorrected for the microdensitometer optics and slit, since this would only affect the level of the curves not their relative scaling to each other.

The final GEM images were made on Kodak 5235 duplicating film process in D-76 at 68° F to give a gamma of 1.0. Exposures were adjusted so that the final scene densities remained approximately the same throughout the entire GEM set.

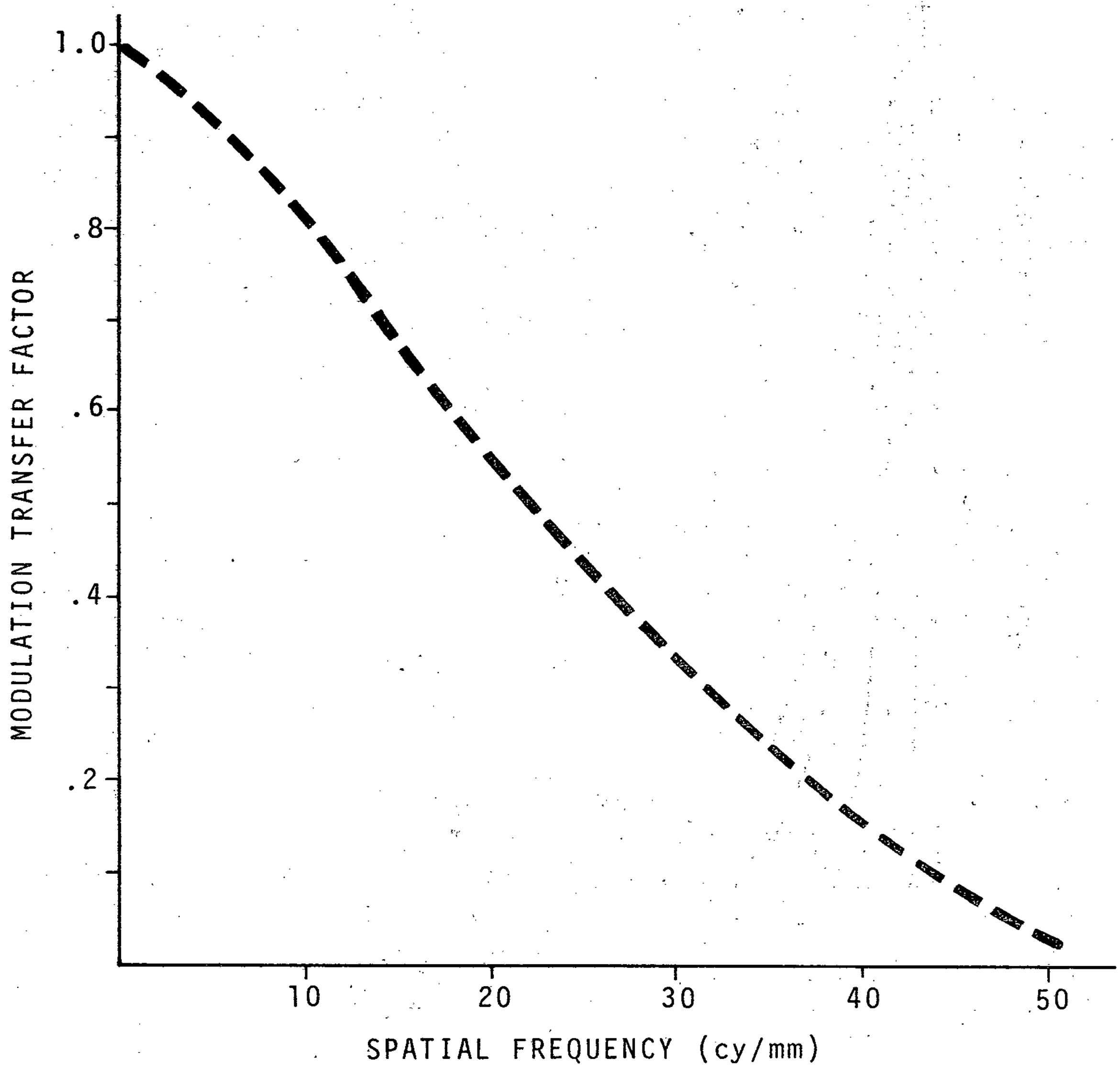

Figure 1. Selected nominal scene transfer function for GEM original negative.

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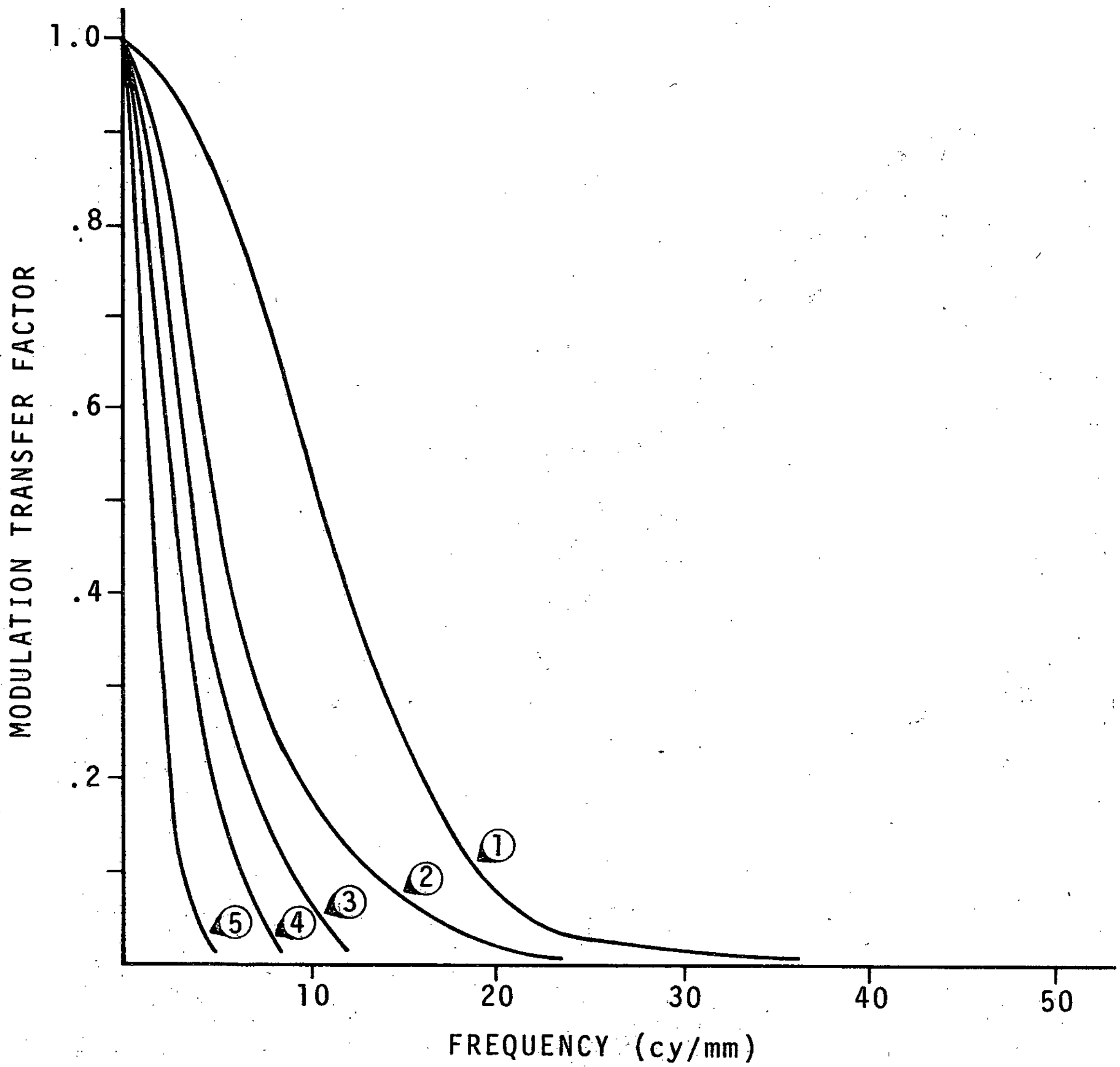

Figure 2. Target edge frequency spectrum.

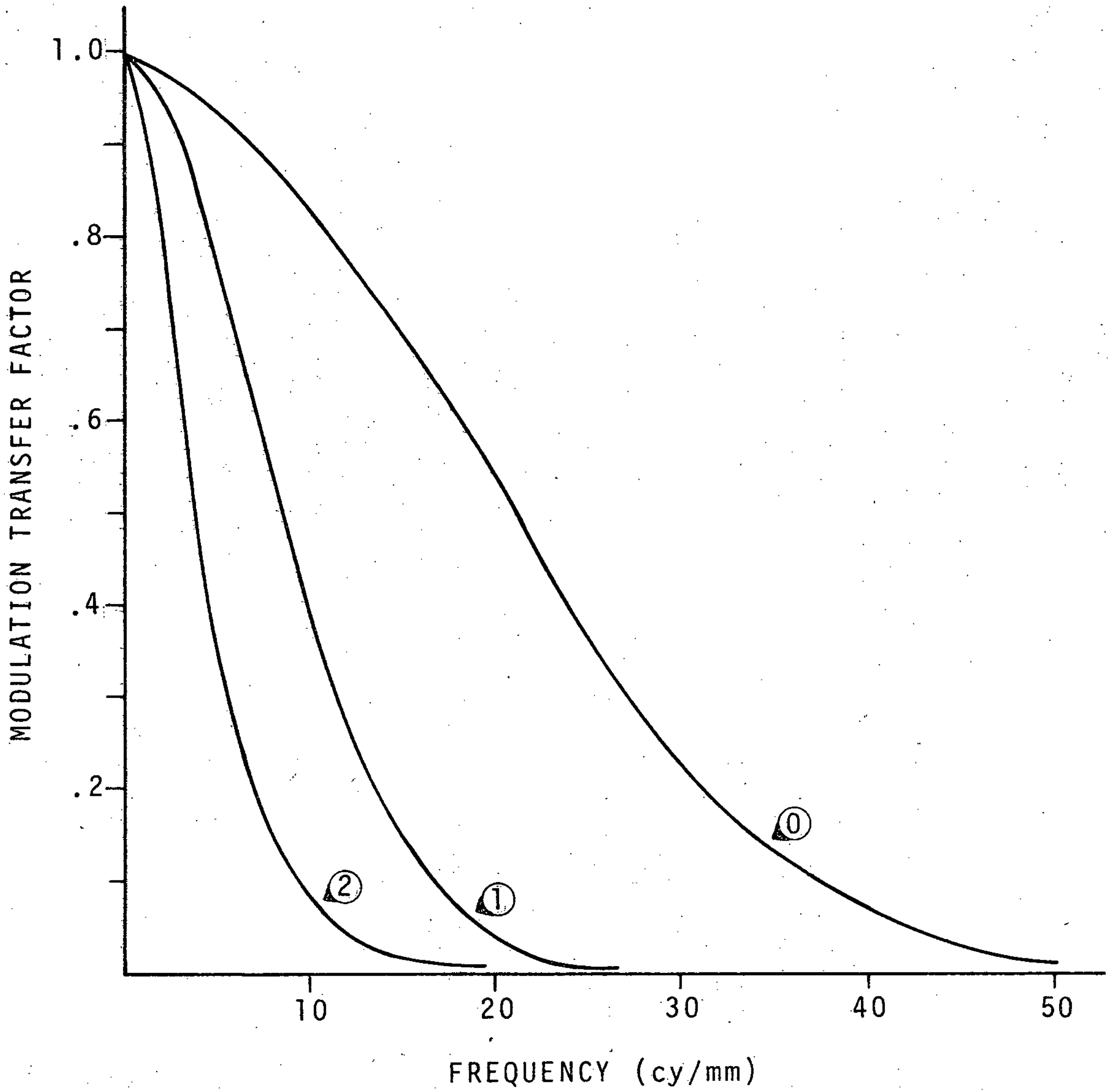

Figure 3. GEM frequency spectrum.

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APPENDIX D

THE PHOTOGRAPHIC IMAGERY

GROUND RESOLUTION

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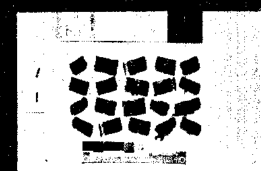
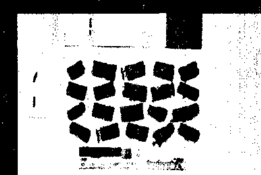
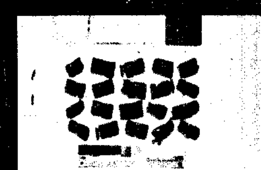


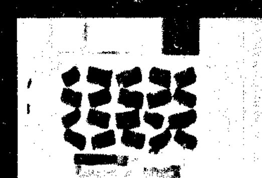
10"



27"



38"



43"